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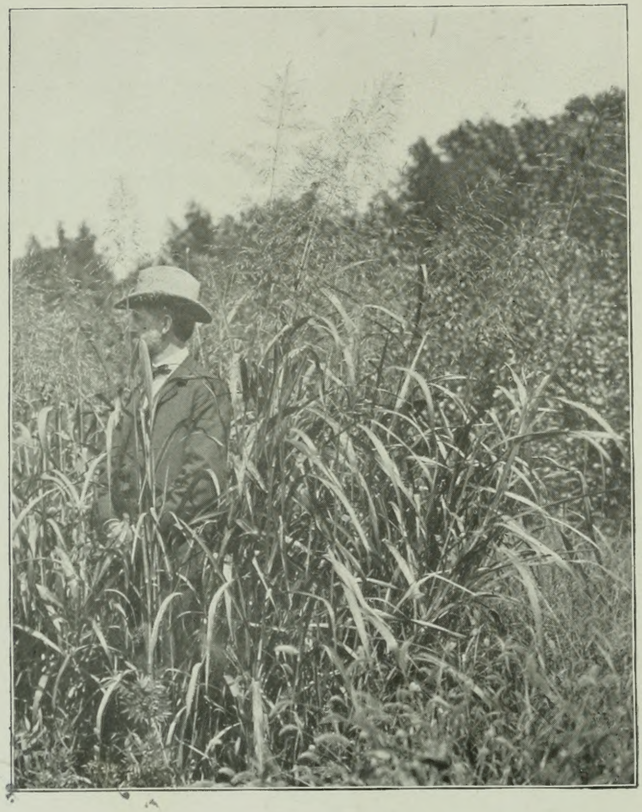

JOHNSON GRASS IN GRASS GARDEN ON GROUNDS OF UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

Gov. Doc.
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U.S. Bureau of Plant Industry,
" Soils, and Agricultural
Engineering

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 11. – 20

B. T. GALLOWAY, Chief of Bureau.

JOHNSON GRASS:

REPORT OF INVESTIGATIONS MADE DURING THE SEASON OF 1901.

BY

CARLETON R. BALL, Assistant Agrostologist,
GRASS AND FORAGE PLANT INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., November 23, 1901.

Sir: I have the honor to transmit herewith a paper on Johnson Grass: Report of Investigations Made during the Season of 1901, by Carleton R. Ball, assistant agrostologist, Grass and Forage Plant Investigations, and recommend that it be published as Bulletin No. 11 of the Bureau series.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

In June, 1901, Mr. C. R. Ball, assistant in the Office of the Agrostologist, was authorized and directed to proceed, under instructions from the Agrostologist of the Department, to points in Alabama, Louisiana, and Texas, for the purpose of making investigations concerning Johnson grass and to gather information for a report on this subject as required by law.[a] He was instructed to carefully study such methods as had been or are being pursued to exterminate this grass and to consult with the commissioner of agriculture of the State of Texas and with others as to plans for destroying Johnson grass where it had become a pest. He was further instructed to make arrangements for carrying on experiments along practical lines with the view of destroying the grass in an economical and effective manner. He was directed to examine carefully the laws of Texas relating to the subject in hand, to study the question of natural or artificial distribution, and, in fact, all points having a bearing upon the question of the value, harmfulness, and methods for destruction of this grass.

In regard to the means of eradication the whole field was carefully looked over and a piece of very badly infested land on the farm of Mr. John Parker, near the town of Taylor, Williamson County, Tex., was selected for the experiment. This selection was made under advisement with the Hon. Jefferson Johnson, State commissioner of agriculture and insurance, in cooperation with Prof. J. H. Connell, director of the Texas Agricultural Experiment Station. The results of the present season's investigations and experiments are presented in the report herewith submitted.

F. LAMSON-SCRIBNER,
Agrostologist.

OFFICE OF THE AGROSTOLOGIST,
Washington, D. C., November 23, 1901.

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[a] House bill No. 121, Fifty-sixth Congress, first session, making appropriations for the Department of Agriculture.

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JOHNSON GRASS: REPORT OF INVESTIGATIONS MADE DURING THE SEASON OF 1901.

By Carleton R. Ball, *Assistant Agrostologist.*

JOHNSON GRASS (Andropogon halepensis (L.) Brot.)

DESCRIPTION.

A stout, erect perennial grass, with rather broad leaves and a large panicle which is open at flowering time. It produces great quantities of underground jointed stems known as rhizomes or rootstocks but popularly called "roots." It is closly related to the sorghums and resembles the ordinary sweet sorghum very much in its habit of growth, except that it is smaller and more slender. The ordinary height is about 5 or 6 feet, but in its ranker growth it sometimes reaches a height of fully 9 feet, with culms or stems nearly one-half inch in thickness at the base. It is a native of the Mediterranean region of Europe and Africa and also of southern Asia.

ORIGIN AND DISTRIBUTION.

Johnson grass was introduced into this country from Turkey about the year 1830—possibly a little later. It is said that Governor Means, of South Carolina, received a request from the Sultan of Turkey to send someone to the Ottoman Empire to instruct the Turks in the art of raising cotton. When the gentleman sent by Governor Means returned he brought with him from Turkey the seeds of a number of plants which were in cultivation there, and among them was the seed of the now famous Johnson grass. About the year 1840 Col. William Johnson, the owner of a large plantation at Marion Junction, near Selma, Ala., was on a visit to South Carolina, and on his return brought with him a quantity of Johnson grass seed which he sowed on his farm in the fertile bottom lands of the Alabama River. Colonel Johnson was the first planter to cultivate the grass in any great quantity and with great success, and it was from him that it received the name now most commonly used for it—Johnson grass. In South Carolina it was known as Means grass, from the name of the governor who was instrumental in its introduction, and that name is still used for it occasionally.

In later years it has been very frequently referred to under the name of Guinea grass, but that name should be restricted to *Panicum maximum*, a widely different plant. It has also been called by a great number of other names at different times and in different parts of the country. Among these names are Aleppo grass, Alabama Guinea grass, Arabian millet, Australian millet, Cuba grass, Egyptian grass, Egyptian millet, Evergreen millet, False Guinea grass, Green Valley grass, Morocco millet, St. Mary's grass, and Syrian grass. Some of these names have been given to it in different localities where it has been grown, while others have been given to it purposely by seed dealers in order to create a demand for the seed of a supposedly new grass. Many of these names refer to the places where it was supposed to have originated.

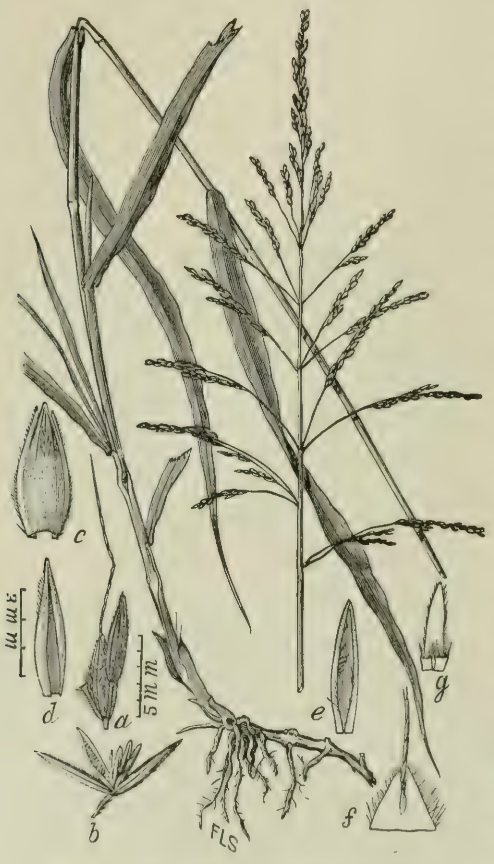

FIG. 1.—Johnson grass (*Andropogon halepensis*).

In the sixty years since it was introduced into Alabama, Johnson grass has continued its westward course until it is now found abundantly as far west as Texas, and in the river valleys and along irrigating ditches of New Mexico, Arizona, and California, extending along the coast region to Oregon and Washington. As a luxuriant and profitable growth, Johnson grass is confined in the Southern States to the fertile alluvial soils of the river bottoms and the black prairie region. It is also found in the poorer sandy or clayey soils of the hills and the pine barrens, but in such regions its growth is less vigorous. Above the latitude of 37°, or about that of Tennessee, it is much less frequent, because it is subject to winter killing during the more severe winters, although it may persist for several years as far north as latitude 42°, or that of central Iowa and New York. In the drier regions of the Southwest it is found in the greatest abundance along the irrigating ditches, while on the Pacific coast it establishes itself very rapidly in the warm, moist, valley lands or in the drier parts along the canals of the irrigation systems.

DISSEMINATION.

When we stop to consider that in sixty years from the time Johnson grass was first cultivated in this country it has spread from the original point of introduction over more than half the United States, we realize that it must either have had especial assistance in order to cover so large a territory or is a plant remarkably well adapted to the conditions obtaining throughout this great area. As a matter of fact, both of these points are true. As the seed was introduced into Alabama for the purpose of cultivation, so it has been carried or sent from Alabama westward to a large number of Southern States. Persons recognizing its great value as a hay and pasture grass have been anxious to secure seed, and wherever they have established their meadows, there they have established a new center of infection for surrounding districts. It is quite probable that the introduction of this grass into most of the States which it now occupies to a greater or less extent was accomplished in just this manner by persons eager to grow this new and highly praised grass. In most of the Southern States it is probable that at one time or another seeds were planted in many places widely separated from each other. On the other hand, it seems almost certain that from the comparatively few centers of infection, which were thus purposely established, the seed had been unintentionally and constantly scattered until in most of the Gulf States this grass may be found on almost every plantation.

The principal and, in fact, almost the only means by which the plant is propagated is by the seed. This is produced in abundance, and is so well protected by the hard and firm coverings that it is enabled to withstand adverse climatic influences. One of the principal ways in which Johnson grass has been distributed so thoroughly is by means of the hay. It has been the custom of planters throughout almost the entire range of this grass to allow the seed to become ripe on the stem before cutting. The seed shatters very readily when ripe, and as the hay was hauled about the plantation to the points where it was to be fed or baled, and the baled hay carted about or carried on wagons to some shipping point, the ripe seed was scattered and an abundant stand of plants the next season was the inevitable result.

Cattle, horses, and other farm stock running at large have been very instrumental in scattering Johnson grass over the plantations. Wherever cattle are grazing on this grass after the seeds are formed large numbers of seeds are eaten. By reason of their hard outer covering the ripe seeds pass unharmed through the digestive tract of the animals and pass out of the body ready to produce a vigorous growth.

Wherever the droppings from such animals are found there is always danger of a growth of Johnson grass. In the same manner the manure from stock fed in the stables or yards will be filled with live seeds, and wherever this manure is scattered as a fertilizer in the fields the result is sure to be a crop of the grass.

The wind and several species of seed-eating birds also aid in scattering the seeds of this pest over the country, but the actual damage arising from this source is undoubtedly small. Floods also assist in the rapid and thorough dissemination of the seeds. As before remarked, Johnson grass is found most abundantly in the rich soil of river valleys. Every time these streams overflow their banks as a result of heavy rains, large quantities of seeds are carried downstream by the high water and scattered broadcast over plantations lying below.

One of the most common ways in which the seeds are scattered is through the medium of seed oats. It has been found quite difficult to separate the seed of Johnson grass from the oat seed, and as wherever oats are sown on land infected with Johnson grass ripe seeds of the latter are almost always harvested in the resulting oat crop, it will be seen how great the danger from this source really is. In this way the grass is carried not only from one plantation to another in the same neighborhood, but as the grain either for feed or seed is widely distributed the pest has been carried from one State or section to another. This has been especially true in the last few years.

The varieties of oats ordinarily raised in the South have been seriously injured year after year by rust. Recently strong efforts have been made to secure a variety which should be practically rust proof. Such a variety has been grown in the State of Texas and has been widely sold throughout the entire Gulf region under the name of Texas rust-proof oats. These oats were largely raised on land where Johnson grass was flourishing, and a large proportion of the grain contained the seed of Johnson grass. Wherever these oats have been sold Johnson grass has been introduced, and many plantations which had been kept scrupulously free from it for many years have been unwittingly seeded to this dreaded pest in this way. It has also been widely scattered along the rights of way of railroads. This has come to pass through the shipments of the baled hay from which the ripe seed has scattered along the track through the motion of the cars, and through the medium of stock cars in which this grass has been used for feed or for bedding the animals.

Johnson grass is also disseminated by means of the underground stems or rhizomes. Wherever a plant is started from seed these strong creeping rhizomes are thrust out and the patch grows slowly but steadily larger each succeeding year. Whenever a plow or other cultivating instrument passes through one of these patches fragments of the stems are frequently dragged for some distance and there establish a new growth of the plant. Occasionally pieces of the stems become wedged in the hoofs of cattle crossing plowed fields and are carried for some distance before coming free again, and where they lodge a new center of infection is established.

CONTROL.

In the consideration which has just been given to the methods by which Johnson grass spreads so rapidly it was found that the ripe seed was the important factor in dissemination. The question of controlling this pest, then, resolves itself directly into the question of controlling the seed production of the grass. In short, the spreading of the grass would be almost completely checked if it were not allowed to produce seed. This may look like a very serious problem, and yet there is little doubt that nine-tenths or more of the Johnson grass which is allowed to mature seed is in cultivated fields or in other places where it is easily accessible and where seed production could be prevented. At the same time it should be remembered that it is in these most accessible fields and patches of the grass that ripened seed does the greatest damage. Except on the comparatively few large plantations where Johnson grass is grown as a hay crop and where its cultivation has been carried on successfully for many years, the utmost carelessness prevails in allowing the plants to mature seed. In a great many meadows which are devoted entirely to this crop thorough cultivation or plowing of the ground is given only at such long intervals that the grass becomes much weakened. Where this is the case the resulting crop is very irregular and uneven in its growth. Some plants will put forth flowers and ripen seed before others show any signs of doing so. The farmer who wishes to get the largest hay crop for his labor delays his mowing until the first seeds have ripened and fallen or are ripe enough to scatter from the hay after it is cut. This method of harvesting the crop should be avoided. The meadow should be so handled that the crop will be developed almost uniformly, as is the case with a crop of wheat or oats, and the cutting could then be so timed as to prevent the ripening of seeds on even the earliest of the plants. It has been noted, especially in the States of Louisiana and Texas, that even where a good, vigorous growth of Johnson grass was to be made into hay the whole field was allowed to ripen its seed before the cutting took place. This policy is not to be approved, because of the dangers arising from the great quantities of seed thus produced and because the hay is practically worthless for feed when cut at that period of its growth. This point, however, is discussed at greater length in another place.

Johnson grass growing along turn rows, fences, and roadsides should be mowed frequently to prevent the ripening of the seeds. In a great many instances, such as farms entirely inclosed by wire fences, a bunch of cattle can be used and the grass thus kept grazed during the growing season. One State (Texas) has a law which deals with the seeding of Johnson grass on the rights of way of railroads. Such areas should be carefully looked after, and the production of seeds should not be allowed in any of the States where the grass is troublesome. There are, scattered about on pieces of land not in cultivation, small quantities of Johnson grass, and these are likely to ripen their seed unmolested unless they are grazed by cattle. The dangers arising from the scattering of seed from these struggling plants are, however, very small compared with those threatened by the wholesale production of seed permitted in cultivated fields and meadows. It is to be understood that this prevention of seeding is not recommended as a means for killing the grass, but simply to check its rapid spread to land heretofore unoccupied by it. No method of extermination is likely to prove successful so long as the area of infested ground is allowed to increase so rapidly from year to year. During the course of this investigation a large number of representative and intelligent planters in the different States visited were asked if, in their opinion, it was not true that nine-tenths of the spread of Johnson grass into places where it is not wanted was due to carelessness in allowing seed to ripen freely. In every case the answer was in the affirmative. The State of Texas alone among the States troubled by Johnson grass has enacted laws dealing with the question. Copies of these statutes are here given verbatim:

[H. B. No. 173, Twenty-fourth Texas legislature. 1895.]

AN ACT to make it a penal offense for any person in this State to unlawfully sow, scatter, or place on land not his own the seed or roots of Johnson grass or Russian thistles, or wilfully or knowingly sell or give away hay, straw, oats, or grain containing or intermixed with the seeds or roots of Johnson grass.

SECTION 1. *Be it enacted by the legislature of the State of Texas*, That if any person in this State shall knowingly, wilfully, and with intent to injure, sow, scatter, or place on any land not his own the seed or roots of Johnson grass or Russian thistle, or wilfully and knowingly sell or give away any oats, hay, straw, seed, or grain containing or intermixed with the seeds or roots of Johnson grass to anyone who is ignorant of the fact that such seeds or roots are so contained in or intermixed with such oats, hay, straw, seed, or grain, he shall be deemed guilty of a misdemeanor, and on conviction thereof he shall be punished by fine of not less than twenty-five dollars and not more than one thousand dollars.

SECTION 2. In prosecutions under the preceding article it shall not be necessary for the indictment to allege the name of the owner of the land, nor shall it be necessary for the State to prove the name of such owner, but it shall be sufficient to allege and prove that the land was not the property of the person accused.

SECTION 3. The near approach of the close of the session of the legislature, and the crowded condition of the calendar, and the fact that it is improbable that this bill can be read on three several days, create an emergency and imperative public necessity that the constitutional rule requiring bills to be read on three several days be suspended, and it is so enacted.

NOTE.—This bill became a law without the signature of the governor.

[H. B. No. 470, Twenty-seventh legislature of Texas. General Laws, Twenty-seventh Legislature, pp. 283–284. 1901.]

AN ACT to prohibit railroad and railway companies or corporations in this State from permitting Johnson grass or Russian thistles from going to seed upon their right of way, and fixing a penalty.

SECTION 1. *Be it enacted by the legislature of the State of Texas,* It shall hereafter be unlawful for any railroad or railway company or corporation doing business in this State to permit any Johnson grass or Russian thistle to mature or go to seed upon any right of way owned, leased, or controlled by such railroad or railway company or corporation in this State.

SECTION 2. If it shall appear upon the suit of any person owning, leasing, or controlling land contiguous to the right of way of any such railroad or railway company or corporation that said railroad or railway company or corporation has permitted any Johnson grass or Russian thistle to mature or go to seed upon their right of way, such person so suing shall recover from such railroad or railway company or corporation the sum of twenty-five dollars, and any such additional sum as he may have been damaged by reason of such railroad or railway company or corporation permitting Johnson grass or Russian thistle to mature or go to seed upon their right of way: *Provided,* Any owner of land or any person controlling land contiguous to the right of way of any such railroad or railway company who permits any Johnson grass or Russian thistle to mature or go to seed upon said land shall have no right to recover from such railroad or railway company as provided for in this act.

NOTE.—This act took effect April 9, 1901, thirty days after adjournment.

The provisions of these laws are excellent, in spirit at least, but as with most other preventive and remedial legislation, their successful enforcement depends largely upon a strong public sentiment of approval. Until this sentiment is thoroughly aroused such laws are apt to be dead letters. This fact becomes strongly evident when one takes into consideration the large number of planters who cry out against this nuisance and yet are engaged in the raising of oats badly infected with Johnson grass. The mixed seeds of the two are largely sold in other States as pure seed oats in spite of legislation to the contrary.

ERADICATION.

A large number of planters who own land infested with Johnson grass are firm in the belief that it can not be killed under any circumstances or by any methods. This may have been true in their own experience, and yet it is to be regretted that when the possibilities of ridding the land of this grass have been fully proved so many allow their prejudice to prevent their achieving similar desirable results. They are convinced that it can not be done, and so refuse to accept these evidences of successful work or to try it for themselves. There is no one method which can be recommended as certain to be successful under all conditions. Within the area of the United States now infested with Johnson grass there is too wide a variation in the conditions of heat and moisture and character of soil to allow of unvarying times and methods of culture. Therefore, in any method much must depend on the good judgment of the cultivator. There is no doubt, however, that fields have been entirely freed from this pest. Instances have been found in almost every community. They are most common in those States where Johnson grass has been longest known and where the planters have become most familiar with it. In some cases these good results have been obtained under field conditions; in others successful results have been obtained where only small patches were concerned. In this latter case the means used would often not be practicable or economical if the work required was on a large scale. A very large number of methods for destroying Johnson grass have been advocated at different times and places. Many of these are worthless, having been advocated by those not very familiar with the plant, in its serious aspect, as a menace to crops. The conditions necessary to the destruction of this grass are simple, but to fulfill them all is a very difficult matter. To entirely rid a piece of land of Johnson grass requires that every seed and plant be destroyed. The seeds in or on the soil must be made to germinate and the young plants killed; all the old plants must be destroyed, and the complex "root" system must be either killed or so discouraged that it will cease to send up green sprouts, and so finally starve to death. There are perhaps three general methods by which it is possible to accomplish these results. The first is by hand labor; the second by field cultivation; the third by the use of chemical substances. The first and second methods are frequently combined.

HAND LABOR.

Hand labor is naturally slow, expensive, and utterly impossible on large areas. For small patches scattered about in fields or gardens or in situations where teams and machinery can not be used to destroy them, hand labor is most economical, having also the advantage of being usually more thorough and less dependent on external conditions than any other method. The plants are uprooted and all the stems to the last fragment removed from the soil, all being hauled away and burned to prevent their taking root again and doing further damage. The great difficulty of this method lies in reaching the depth necessary to find all the stems, and it is also always uncertain that every one of the small fragments has been removed from the soil; but both must be done before there can be any assurance that the spot is free from danger of a new crop. The question of hand labor as a factor in destroying this grass will be considered in connection with certain patent methods.

CULTIVATION.

When it is desired to destroy Johnson grass by cultivation, there are a variety of methods that may be employed. The land may be fallowed in summer or in winter, or it may be worked in some crop.

A combination of two of these may be used. The purpose of cultivating in summer fallow is to expose the underground stems to the heat of the sun; that of cultivating in the winter fallow to expose them to the action of frosts.

WINTER FALLOW.

The method of winter fallowing the land and frost killing the grass can be used in only a small part of the large Johnson grass region. The grass does not usually become very troublesome where the climate is cold enough to allow of killing the exposed stems by frost. There is, however, a considerable area in the northern part of the Johnson grass belt where this method will be quite successful in the average winter. The performance is quite simple and very effective. The field is plowed up in the late autumn to a depth of about 3 or 4, or even 5, inches, depending on the amount of frost that may be expected. This soil is left exposed until the stems in the turned portion have been killed by the cold. The ground should then be plowed again, preferably crosswise to the first plowing. The second plowing should go to a greater depth than the first, in order to turn up a new layer of fresh, uninjured stems. By plowing crosswise the second time any stems left deeply covered in the turned soil at the first plowing are more apt to be exposed, while any cutting and covering done during the first operation would be unfailingly remedied by the second. Ordinarily two plowings would be sufficient for the purpose. No doubt some pieces of stems will survive even this treatment. Where the number is small and the patches scattered, it is best to dig them out by hand during the growing season.

SUMMER FALLOW.

The most uniformly successful method of destroying the grass is that of summer plowing fallow land. The field may be sown in the fall to some grain crop, to be taken off in the late spring. If the land is a meadow, one cutting of hay may be secured before the time for the destruction of the grass. The best time to commence the process of eradication varies. It must be done during the six weeks or two months when the longest period of hot, dry weather may be expected. This will be between the last of June and the first of September ordinarily. It may, however, commence as early as June 1, or even in May, as was the case the past summer. If the grass is growing vigorously at the time the plowing is begun, the more surely will it be killed by the disturbance and exposure of its stems. If it is in a resting condition, any cultivation during the growing season will serve only to promote a more rapid growth unless the grass has been greatly weakened by previous unfavorable conditions.

At the first plowing the soil should be turned to a depth of 2 or 3 inches or a little more. This will depend upon the mechanical condition of the soil and the quantity of stems present in it. If the soil is loose and open and the quantity of stems in it is not great enough to form a compact sod, the land may be safely turned to a depth of over 3 inches. If, however, the land is of a firm and tenacious character, turning up in clods or sods, or if the stems are abundant enough to produce this effect, the plowing should be shallower. In any case the soil turned over must not be deeper than the sun will penetrate with killing power; otherwise that portion of the stems buried most deeply by the turning will remain uninjured and will be stimulated to vigorous growth. This renders the labor of destruction more difficult than if a shallower stratum had been turned and all the stems included in it killed by the heat. In some cases it may be desirable to use a disk or acme harrow on the land immediately after the first plowing, both in order to level the surface if it be clodded and to expose more of the disturbed stems than would otherwise be done. The field should then be allowed to remain undisturbed until the sun has had time to do its effective work and until a new growth has appeared from that portion of the stems below the level of the first plowing.

When this growth has reached a height of about 5 inches, showing that the living rhizomes are again vigorous, the second plowing should be given. This should be done crosswise of the field, or at right angles to the first plowing, in order to certainly remedy any cutting and covering done during the first plowing. The second plowing should be about 2 inches deeper than the first if possible. This also will vary with the condition of the soil and the depth of the first plowing. The idea is to turn up a fresh layer of the underground stems to the action of the sun, and the same requirements as to the thickness of the layer of fresh stems thus turned should be observed.

The success of this method of summer killing will be seen to depend very largely upon the length of time during which dry, hot weather is maintained. If a period of rain should set in after the first plowing has been done and before the stems exposed by the plowing are dead their vigor will be increased and the length of time necessary to kill them will be thus extended. In that event as many as three plowings might be necessary in order to complete the work of destruction. However, in most of the Johnson grass belt several weeks of fairly hot and dry weather may be confidently looked for during the summer.

Where the soil is not too hard or lumpy a spring-toothed harrow may be used to drag the stems from the soil after plowing. They can then be collected and burned. Even under the most favorable conditions it is probable that some stems will escape destruction and produce new growth when the rains commence. The importance of completely ridding the field of the grass can not be too strongly urged. The small scattered patches do not at first appear troublesome or dangerous, and too often they are neglected and allowed to quickly reseed the whole field. A comparatively small amount of labor will clear them out to the last stems, and the desired result will thus be secured. If this is not done the good results of the repeated plowings are lost and the field is soon as bad as ever.

CULTIVATION IN CROPS.

Many planters have testified that they have cleared their fields of Johnson grass without interrupting the ordinary system of cropping. In some instances this has been done in a single season. In others it has been accomplished only in from three to five years of labor. The crop raised is usually cotton, and the method always involves a large amount of hand labor. This method is expensive, and yet where it can be practiced the more thorough cultivation thus given is repaid by the increased yield of the crop. To be successful it must be entered into in no half-hearted way, as it always demands careful work and unrelaxed vigilance. At every plowing or cultivating of the land the stems exposed on the surface are removed from the field and destroyed. Plants persisting in the rows are dug out and destroyed when the crop is hoed, and this constant warfare is repeated month after month and year after year, if necessary, until the land is free.

PATENTED METHODS.

A Texas company has patented a cultural method of killing the grass. This method has been widely advertised and has been the subject of several inquiries received by this office from Texas planters. For these reasons a thorough investigation of the method was made.

The process of this company is as follows: The ground is broken to a depth of about 3 inches some time during the winter. The broken ground is then pulverized with a harrow as deep as it was broken, for the purpose of breaking up the rootstocks and stimulating an early and vigorous growth of the grass in the spring. The grass is then allowed to grow undisturbed until about the middle of April, when the land is again broken and the green grass turned under. About one week after this second breaking the ground is again pulverized as deeply as plowed. The land, whether allowed to remain fallow or planted in cotton, is then cultivated from five to eight times during the season. The intervals between the cultivations extend from a week to twenty days, depending upon the growth of the grass, which should be allowed to make a good, vigorous start between cultivations. Each cultivation should be made as deep as the land is mellow, which should be 6 or 8 inches after several cultivations, the purpose being to stimulate the grass to the greatest possible growth, and by never allowing it to reach any considerable height its vitality will finally be exhausted and it will thus be killed.

If this method is used on fallow land it will be seen that a much greater amount of work is required than would be necessary by the process of summer cultivation outlined above. It is also required that the work be done during the spring and early summer when planters are usually very busy. If, instead, the land be cultivated in a cotton crop during these operations the fact that the land can be broken or cultivated in but one direction only renders the labor much more difficult. The plants which are growing in the cotton row are untouched by the frequent deep cultivations and continue their growth unchecked. In order to exterminate the plants the slow and expensive method of digging them out by hand must be employed. If successfully done this method also endangers the life of the young cotton plants. The principles on which this method of extermination are based are doubtless sound, but the successful working out of the method is always expensive. For this reason it is not likely to be adopted by any of the numerous renters who make up a large proportion of the agricultural population in all the Southern States. It must also be remembered that since this method has been patented it can not be used by any planter except by the consent and under the direction of the patentee. The charge made by this company for directing their methods during the past season was $2 per acre. In return they guaranteed that if directions were implicitly followed the grass would be exterminated. There is no doubt that the same amount of labor expended during the late hot summer could be much more cheaply performed and would be equally successful. The payment of the bonus of $2 per acre would not be required and the planter would take advantage of a season when his growing crops did not demand all his attention.

USE OF CHEMICALS.

A variety of chemical substances have been employed for destroying Johnson grass. Among these are salt, kerosene, lime, bleaching powder, and some more complex mixtures, such as nitrate of soda and white arsenic or arsenious acid in water. A certain proportion of these last-named chemicals has been patented for this purpose.

Common salt has frequently been used by planters for killing this grass. It is generally applied broadcast, but is sometimes used as a brine. So far as known, it has never been used on any large fields of the grass, but commonly only on small patches, in gardens, etc. The effect of salt, when used in definitely known quantities, has not been determined, because on the small patches no record is usually kept of the amount actually used or of the size of the patch. It is quite certain that in such cases a larger amount per acre is used than could be profitably applied in large areas. There is also considerable uncertainty as to the actual value of salt in any quantity. Some planters have reported that when applied in a layer 2 inches deep on the surface of the ground the grass was killed. Others report results directly opposite. Wherever it is applied in the dry form there is always danger of much of it being washed away if the first succeeding rain happens to be heavy. The effect of salt upon the roots beneath the surface is entirely lost unless it is carried into the ground. It can not be recommended as an effective agent for field use.

Kerosene has been used in about the same way as salt. Its value as a destroying agent is doubtful. Mr. David Williams, of Washington, Tex., reported using about 1 gallon on a patch 6 feet square with perfect success. No Johnson grass appeared in the two years following. The oil used in this case was probably refined oil, which is expensive. Since the discovery and opening of the great oil fields in southern Texas, crude oil can be secured at a much lower rate than the refined article, and it would probably be quite as effective for killing vegetable growth as the refined oil. It would, however, be much more difficult to apply the crude oil on account of its thicker consistency, but for this same reason it would not be as easily washed from the soil.

Chloride of lime or bleaching powder has also been recommended for this use, but its value has not been definitely proved. The solution of white arsenic and nitrate of soda, referred to above, was patented in 1898 by Mr. William A. Chapman, of Cleburne, Tex., and is made and used in the following manner: One pound of white arsenic is introduced into 6 gallons of water and boiled until the arsenic is dissolved. The mixture is then completely cooled and 1 pound of nitrate of soda is dissolved in it. The addition of the nitrate of soda is for the purpose of holding the arsenic in solution, as otherwise it would recrystallize in the water and a repeated boiling would be necessary each time it was desired to use the solution. The poisonous element is the arsenic. It is intended to apply this liquid with a sprinkling pot, and one or perhaps two applications are recommended. No further information as to this patent compound has been secured.

ELECTRICITY.

Electricity has frequently been advocated as a sure method for eradicating all vegetable pests. A few years ago it was reported that a company was being organized in Fresno, Cal., to utilize this method, but nothing further has been heard of it. Electricity can not be satisfactorily and economically used until different and less expensive methods of applying it are discovered.

UTILIZATION OF JOHNSON GRASS.

So great an evil has Johnson grass become in the grain fields and cotton plantations that many planters and others have become violently prejudiced against it. They refuse even to listen to the suggestion that it makes a valuable and nutritious hay, and wish to hear of nothing but its complete and rapid extermination. Nevertheless, the fact remains that in the States of Georgia, Alabama, and Mississippi, where the grass has been long established, many hay farms of several hundred acres each now exist and have existed for years. On some of these, as for instance those in the Alabama Valley in the vicinity of Montgomery and Selma, or in the famous Delta of Mississippi near the Yazoo River, the production of Johnson-grass hay has been found very profitable on lands which rarely produce less than a bale or a bale and a half of cotton per acre. Of course, on these rich lands the yield per cutting and the number of cuttings obtained in a single season will, as a general rule, be greater than on poorer soils. At the same time, the profit from any crop is less on poorer soils than on the richer, so that under these conditions Johnson grass at the prices of hay for the past few years is a profitable hay crop throughout the Southern States. It has advantages over several of the commercial crops which can be raised in those States. In the first place, a meadow can be very easily set in Johnson grass if that be desirable. On many plantations, however, good meadows, or what would quickly make good meadows if permitted, have already been formed, and the growth is vigorous, luxuriant, and long continued. The yield is large, and the quality of the hay when cut at the proper time is not exceeded by any other hay on the market, although this may sound like a strong statement. Of course, Bermuda hay is finer and probably yields more food, ton for ton, but the yield per acre is not usually as large, while the labor of cutting and curing is greater, and the hay is so fine that considerable of it is wasted in feeding. In most markets where Johnson-grass hay comes into competition with other hays it does not sell for as high a price, it is true, but this is due to several causes, chief among which is probably the fact that the hay has not been of first quality because of having been allowed to become mature and woody before cutting. There is also a strong prejudice against it, because so much of it contains ripe seed which the users are afraid of introducing into fields.

There have been many inquiries concerning the nutritive value of Johnson grass, and two tables of chemical analyses are given to show this value. Table I, adapted from Bulletin No. 20 of the Texas Agricultural Experiment Station, shows the composition of the grass at different stages of growth. The amount of water is first calculated and then the percentage of the ingredients in the dry material. The carbohydrates and albuminoids of this table are the same as the nitrogen-free extract and the protein, respectively, of the second table. The total nitrogen given in the third line from the bottom is the amount of that substance in the albuminoids or protein, and is the sum of the albuminoid and amid nitrogen given in the last two lines of the table.

TABLE I.

	Time when cut and state of growth.					
	April 2—6 inches high.	April 10—8 to 10 inches high.	April 21—12 to 18 inches high.	April 29—18 to 30 inches high.	May 7—seed in dough state.	May 18—seed mature.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Water	81.06	77.44	86.09	80.9	76.5	69.33
Ash	11.24	11.62	11.68	10.38	7.98	6.36
Ether extracts (fats)[a]	5.59	8.60	8.10	6.52	4.11	4.07
Crude fiber	21.55	18.74	24.56	25.29	33.32	33.66
Carbohydrates	46.2	41.5	32.41	43.75	45.15	46.10
Albuminoids	15.42	19.54	23.25	14.06	9.44	9.81
Total nitrogen	2.78	3.12	3.73	2.25	1.51	1.57
Albuminoid nitrogen	2.55	2.72	2.73	1.96	1.34	1.40
Amid nitrogen	.23	.40	1.00	.29	.17	.17

[a] The ether extract in this and in the analyses of the other grasses, especially in the younger plants, represents more than the true fats, owing to the large amount of coloring matter removed.

It should be remembered that only a large series of analyses at different stages can show conclusively at what period the grass has the highest nutritive value. This may differ from the time when it has the highest feeding value to the farmer. To him the time when the grass gives the largest yield must also be taken into consideration. This may not be exactly the time when its nutritive value is highest. The time for cutting Johnson grass, as above stated, is when just in flower or a little earlier than the "dough" stage of Table I. It will be noted that the percentage of water and ash or mineral matter in the table gradually decreases as the plant gets older. The carbohydrates are about the same at both ends of the test. The valuable albuminoid or muscle-making material is greatest when the plant was 12 to 18 inches high, after which it decreases rapidly, while the crude fiber increases with the age of the grass. From this table Johnson grass would appear to have the greatest nutritive value when about 20 inches high or perhaps a little more, but of course the yield at this period would be considerably less than when the grass is in flower. Larger series of analyses would be very helpful in more accurately determining just when the grass should be cut.

Table II contains comparative analyses of timothy, redtop, Johnson grass, and red clover hays. The figures for timothy are the average of 68 analyses; for redtop, the average of 9 analyses; for red clover, 38 analyses; and for Johnson grass, 3 analyses of air-dried hay and 7 analyses of the water-free substance.

TABLE II.

Kind of forage.	Fresh or air-dry substance.						Water-free substance.				
	Water.	Ash.	Crude protein.	Fiber.	Nitrogen-free extract.	Ether extract.	Ash.	Crude protein.	Fiber.	Nitrogen-free extract.	Ether extract.
Timothy hay	13.2	4.4	5.9	29.0	45.0	2.5	5.1	6.8	33.5	51.7	2.9
Redtop hay	8.9	5.2	7.9	28.6	47.4	1.9	5.7	8.7	31.4	52.1	2.1
Johnson grass hay	10.30	6.77	7.30	29.34	44.12	2.16	6.62	6.44	34.22	50.89	1.96
Red clover hay	15.3	6.2	12.3	24.8	38.1	3.3	7.3	14.5	29.1	45.2	3.9

From this table we see that an analysis of three samples of Johnson grass shows it to contain very nearly as much protein as redtop hay, and considerably more than timothy hay, the figures being 7.3 per cent, 7.9 per cent, and 5.9 per cent, respectively. None of them contain as much as the rich red clover. In the water-free substance, however, the Johnson grass shows a little less protein than either of the other grasses; in fat, too, it averages a little lower. The amounts of fiber and nitrogen-free extract do not differ enough from those of timothy and redtop to deserve special mention. When we consider that Johnson grass yields much heavier than either timothy or redtop, and that it is nearly equal to these in feeding value, we realize that it is an exceedingly valuable hay grass for the Southern States.

It must not be forgotten that in order to properly produce this hay intelligent care and cultivation of the meadow is necessary. Any idea that a meadow once set may be cropped indefinitely without further treatment must be abandoned at once. To secure the best results, both in quality and quantity of forage, the meadow should be broken up at least every second year. If this thorough plowing is delayed longer than the third year the growth of the grass is greatly weakened by the crowding of the growing rootstocks or underground stems and the consequent checking of the growth of the grass. The meadow should be given a thorough plowing to a depth of several inches, and the land should then be harrowed until smooth in order to present a good surface for mowing. There need be no fear of destroying the meadow if this plowing is done in the spring, or in the fall where there is little danger from winter frosts. The vigor of the plants is greatly increased by this thorough breaking up of the matted stems, and the following crop will be even and luxuriant in growth.

The grass should be cut when the flower heads have begun to open. If cut at this time the hay made from it will be of the finest quality and there will be no danger from ripened seed. The yield may not be quite as large per acre, but the quality will be better, and the grass will renew its growth more rapidly.

Some of the most successful planters in the Johnson grass region make a practice of sowing some other crop on the meadow when they break it up. Oats may be sown, and an early spring crop of good oat hay be thus secured. This crop will contain some Johnson grass, but not much. The second cutting will be earlier if following an oat crop than if the grass be allowed to grow alone. Another practice which serves two good purposes is the sowing of cowpeas in the Johnson grass meadow when it is broken. This may be done at any time during the spring or early summer. The cowpeas will not only furnish excellent hay, which combines well with the Johnson grass hay as a feeding ration, but, as is well known, they also help to restore the fertility of the soil. Such a sowing is therefore especially desirable wherever meadows are established on the poorer soils. If the growth of Johnson grass is more rapid than that of the pea vines, and there is dangeı of the latter being choked out by the vigorous grass, the mowers should be run over the meadow with the bar raised high enough to cut the tops of the Johnson grass without injuring the pea vines.

Johnson grass is not of especial value as a pasture grass. Its growth does not begin until rather late in the spring and does not last after the first heavy frost of autumn. Throughout its range, however, it is grazed to quite a large extent during the summer and affords an abundant and nutritious pasturage. This is especially true in moist or irrigated soils where its summer growth is not checked by drought. All kinds of farm stock graze it well and thrive upon it. There is a rather widely prevalent idea that it can be killed by pasturing. The growth of the grass is much checked and weakened by close pasturing, especially if continued for several years in succession. This is due not so much to trampling and grazing as to the close crowding and matting of the stems in the soil, thus literally choking the grass out. The remedy for this is to break up the land every third or fourth year, thus giving the stems a new and vigorous impulse to growth.

A few cases of cattle having been poisoned by grazing Johnson grass have been reported. These reports have been noted only through the papers, none having been made directly to this Department. Authentic details are rarely given in such cases, and very little weight can be given to these rumors. Since Johnson grass is closely related to sorghum, which is known to be poisonous under some circumstances, it would not be surprising if Johnson grass should also be poisonous under like conditions. Investigations have been conducted for several years to determine the cause of sorghum poisoning, but as yet without conclusive results. Neither sorghum nor Johnson grass is likely to be abandoned as a stock food, however, because of the infrequent danger from poisoning. In comparison with the great number of cattle fed or pastured on Johnson grass the reported cases of poisoning are extremely rare.

SUMMARY.

Johnson grass is a tall, vigorous grass, closely related to the sorghums, with a very strong system of long, jointed, underground stems, popularly known as roots. Each joint of this underground stem is capable of producing a new plant.

It is a native of the tropics of the Old World, and was first introduced into this country as a hay grass in South Carolina about sixty years ago.

It has spread rapidly throughout the entire south to the Pacific coast and thence north to British Columbia. It thrives best in rich, moist, alluvial or irrigated soil, where it is also most difficult to eradicate.

It is commonly spread by means of its seeds. They are widely scattered from hay cut after the seed has matured, and are often planted with seed oats. The seeds are unharmed by passing through the digestive tract of animals, and are thus widely scattered in manure.

The grass should never be allowed to ripen its seeds in meadows, fields, or along roads, fences, or railways.

It can be destroyed by hand labor—digging out the underground stems.

Under field conditions it is best killed by plowing fallow land during hot, dry weather. The stems are thus exposed to the heat of the sun and soon killed. The same result follows the action of severe frosts.

It can also be killed during the cultivation of a cotton crop by much extra hand labor.

Various chemical substances have been tried but none have thus far proved successful and economical.

Johnson grass makes a very good quality of hay when cut while just in flower, and it may be profitably cultivated throughout the South for this purpose. Meadows should be broken up at least every third year to loosen the matted stems. It is not necessary to reseed meadows when thus treated.

Cow peas may be sown in the grass when it is broken in the spring. When broken in the fall, oats may be used with it. It affords good pasture during summer when treated in the same way as meadows.

O

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 12.

B. T. GALLOWAY, Chief of Bureau.

STOCK RANGES OF NORTHWESTERN CALIFORNIA:

NOTES ON THE GRASSES AND FORAGE PLANTS AND RANGE CONDITIONS.

BY

JOSEPH BURTT DAVY,

Assistant Botanist, Agricultural Experiment Station, University of California.

PREPARED UNDER THE DIRECTION OF THE AGROSTOLOGIST,

GRASS AND FORAGE PLANT INVESTIGATIONS.

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1902.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., November 23, 1901.

Sir: I have the honor to transmit herewith a paper entitled Stock Ranges of Northwestern California: Notes on the Grasses and Forage Plants and Range Conditions, and respectfully recommend that it be published as Bulletin No. 12 of the Bureau series. The paper was prepared by Mr. Joseph Burtt Davy, assistant botanist of the Agricultural Experiment Station, University of California, and was submitted by the agrostologist.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

This report entitled Stock Ranges of Northwestern California: Notes on the Grasses and Forage Plants and Range Conditions, was prepared under my direction by Mr. Joseph Burtt Davy, assistant botanist of the Agricultural Experiment Station of the University of California. Mr. Davy, under commission from the United States Department of Agriculture, through this Office, dated March 24, 1900, made a very thorough investigation of the grasses and forage plants of northwestern California, a region whose forage resources have not heretofore been carefully studied. The report contains a comprehensive account of the whole region, its physiographic and climatic conditions, and all the features bearing upon the forage problem. The information it contains will be of use to ranchmen and dairymen and all those interested in the stock industry, and will be found of special value to those living within the region which it covers. In addition to the presentation of this report, Mr. Davy collected a large and valuable series of specimens of the native grasses and other plants which supply more or less grazing, and a set of these specimens has been added to the collections of the Office.

Mr. Davy wishes to express here his sincere thanks to Dr. Walter C. Blasdale for invaluable assistance rendered in the collection and preparation of specimens, for taking and preparing the photographs which illustrate this report, and for help in many other ways. Without this assistance the investigation could not have been successfully accomplished.

F. LAMSON-SCRIBNER,
Agrostologist.

OFFICE OF THE AGROSTOLOGIST,
Washington, D. C., November 25, 1901.

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STOCK RANGES OF NORTHWESTERN CALIFORNIA: NOTES ON THE GRASSES AND FORAGE PLANTS AND RANGE CONDITIONS.

INTRODUCTION.

PHYSICAL FEATURES OF THE REGION.

Northwestern California as here defined includes the counties of Lake, Mendocino, Humboldt, Trinity, Del Norte, and the portion of Siskiyou lying west of the California and Oregon Railroad. It is approximately bounded by lines drawn at 39° and 42° north latitude, and 122° 30′ and 124° 30′ longitude west of Greenwich. (See Map I.)

It is a fairly well-defined topographical area, bounded on the east by the inner Coast Range Mountains and on the west by the Pacific Ocean. It covers the whole of the drainage basins of the Eel, Mad, Trinity, Lower Klamath, and Smith rivers and the smaller streams along the coast north of the Gualala River. On the south it extends beyond this naturally delimited area to include Lake County and the southern boundary of Mendocino County, thereby taking in the drainage basin of Clear Lake and the headwaters of Russian River.

AGRICULTURAL SUBDIVISIONS.

This region is divisible into seven agricultural areas, which are more or less clearly marked topographically, climatically, and phytologically. They are:

1. The Interior Plateau Belt, dissected into long ridges separated by deep canyons, some of them running in a more or less northwesterly direction, other and shorter ones almost due west. This belt is bounded on the west by the redwood forest and on the east by the Mayacama, Yallo Bolley, and South Fork mountains. Lying at a higher altitude, 2,000 to 4,000 feet, it enjoys a warmer summer temperature and less moisture than the Coast Bluff belt; also its soil is heavier, containing more clay and less sand. With the exception of a few mountain valleys included within its limits this is almost exclusively a pastoral area.

2. The Coast Bluff Belt, a narrow stretch of agricultural and pastoral land varying from 1 to 3 miles in width, and occupying a mesa or

bench between the shore line and the summit of the first mountain ridge, which is about 1,600 feet high. This ridge marks the western edge of the redwood belt. For the most part this belt is elevated some 50 or more feet above the sea, but at Humboldt Bay and Crescent City it has been eroded almost to sea level, there forming a large and very fertile flood plain. It is subject to heavy summer fogs, enjoys a more equable summer climate and a greater amount of moisture than is found in the interior, and is relatively cool. The soil is considered poor except at a few points; it is light, being abundantly charged with drift sand.

3. The Redwood Belt, lying between and parallel with the coast bluff belt and the interior plateau, and consisting of rough ridges, separated by narrow V-shaped canyons. It is covered by a more or less dense growth of redwood (*Sequoia sempervirens*), and is a climatic and phytological rather than a geographical area, embracing and being limited to the redwood forest. It runs almost the whole length of the coast of northwestern California, apparently being interrupted in only one or two places, and lies for the most part away from the coast line, sheltered from cool and violent winds behind a ridge which runs nearly parallel with the shore. Scattered redwood trees are but rarely found outside of this belt, which comprises the forest proper. The heavy summer sea fogs, drifting high overhead across the narrow bench of bluff land, are intercepted in their course by the trees on the summits of the ridges, or, when they lie low, roll along the broad river valleys and more numerous narrow canyons opening into the redwood forest, saturating the tree tops, and by their means also the soil below, with abundant moisture. The actual conditions which delimit this redwood belt are not at present clearly understood, but climate appears to have been, above any other evident physical cause, a potent factor in the development of the forest. The soil conditions appear to be generally comparable to those of the plateau canyons, except for the additional amount of humus due to the presence of the trees.

4. The headwaters of the Russian River, forming a connecting link between the distinct topographical region of northwestern and that of western middle California, otherwise called the San Francisco Bay region, to the latter of which it strictly belongs. It is included in this report because it lies within Mendocino County and because it was the starting point of the expedition.

5. The drainage basin of Clear Lake, for the most part a stony and mountainous region, walled in on all sides, and with little level land. Its resources are mainly pastoral, though the lake is fringed by some rich farming and fruit land.

6. Trinity County, an isolated mining region, almost walled in by high mountains, and including the headwaters of Trinity River. Scarcely anything is known of the botany of this very distinct topo-

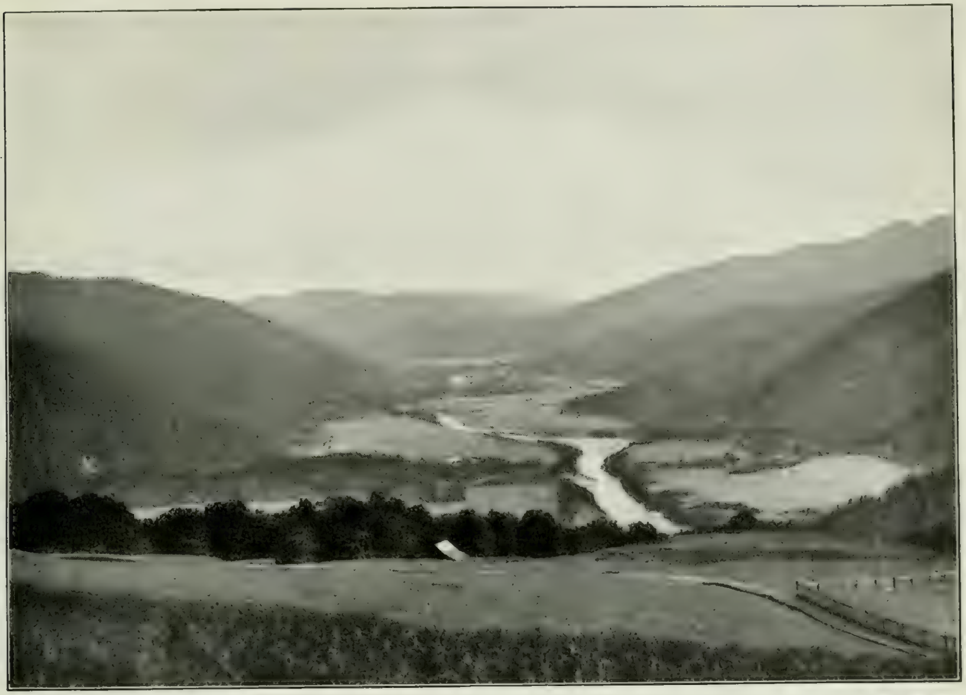


FIG. 1.—HUPA VALLEY FROM THE MOUNTAINS, LOOKING SOUTH.

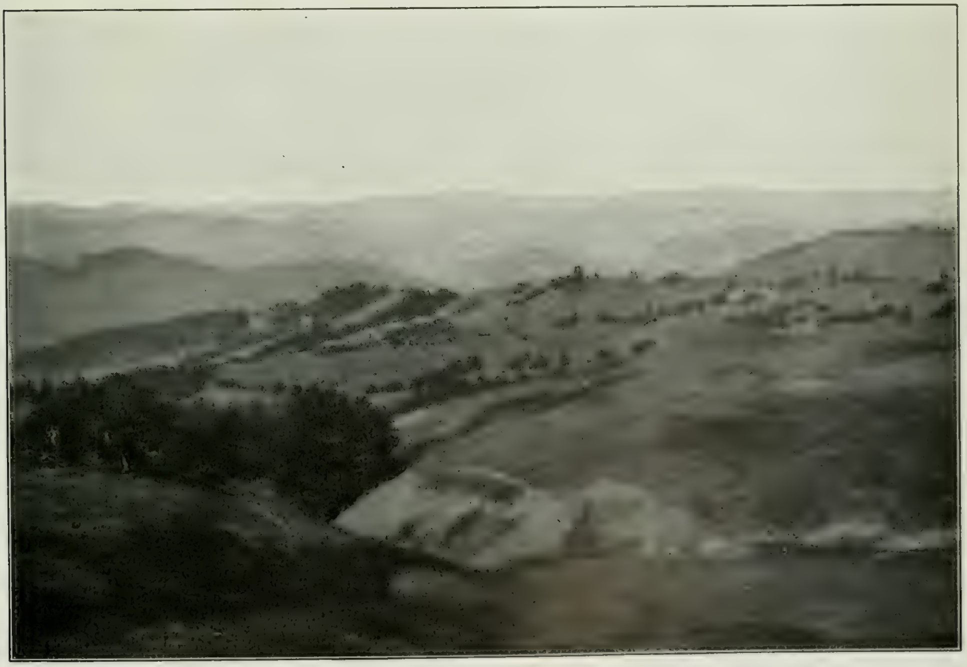
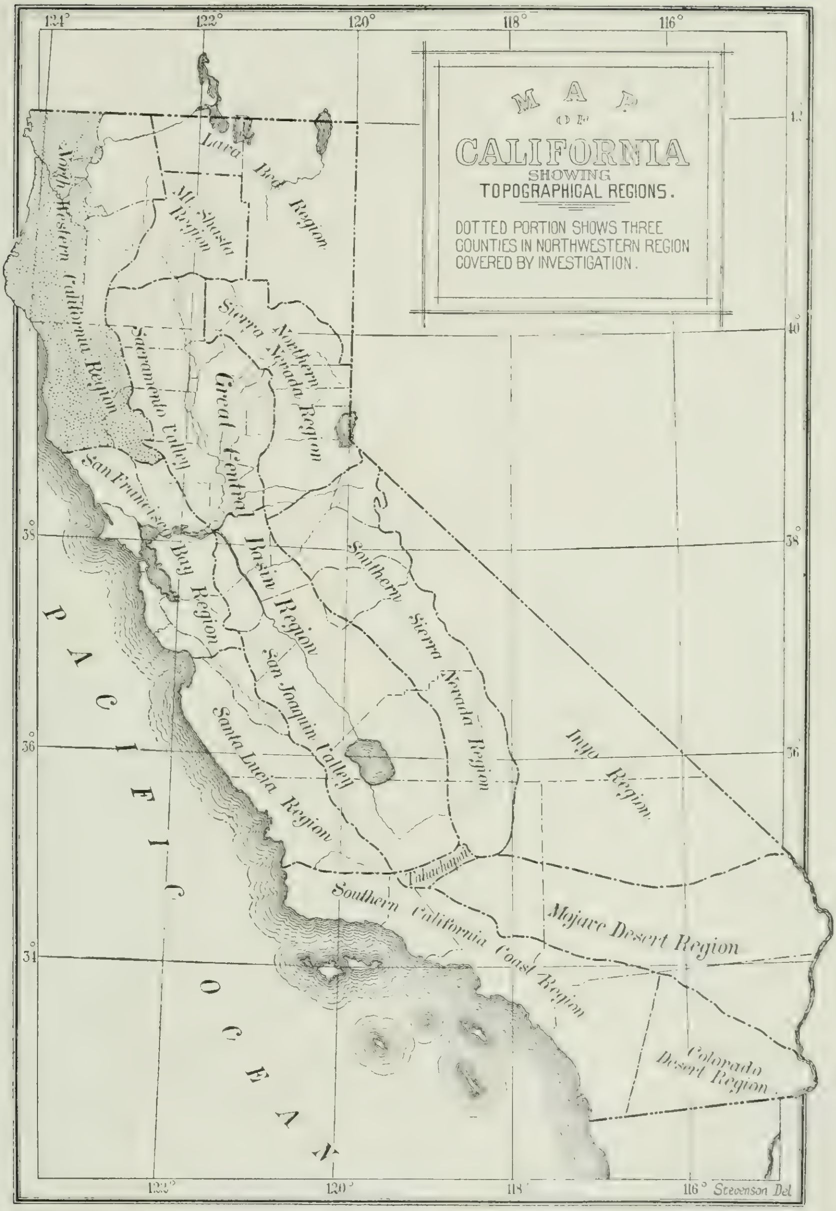


FIG. 2.—SUMMIT OF THE PLATEAU ABOVE HARRIS, LOOKING WEST, SHOWING THE UPLAND RANGES, THE MOST IMPORTANT PASTORAL AREA IN THE REGION.


MAP OF CALIFORNIA
SHOWING
TOPOGRAPHICAL REGIONS.
DOTTED PORTION SHOWS THREE COUNTIES IN NORTHWESTERN REGION COVERED BY INVESTIGATION.
124°
122°
120°
118°
116°
40°
38°
36°
34°
Lava Bed Region
Mt. Shasta Region
North Western California Region
Sacramento Valley
Northern Sierra Nevada Region
Great Central Basin Region
San Francisco Bay Region
Southern Sierra Nevada Region
San Joaquin Valley
Santa Lucia Region
Inyo Region
Tahachapai
Southern California Coast Region
Mojave Desert Region
Colorado Desert Region
PACIFIC OCEAN
Stevenson Del

graphical area, but the collections of Chestnut and Drew[a] indicate that it may be phytologically distinct from the section west of the South Fork Mountains. A collection of plants, including several grasses, has been made by Miss Eastwood during the summer of 1901.

7. The Siskiyou, Scott, and Salmon mountains. Collections of grasses from this region were made by Mr. T. H. Gilbert in the summer of 1899 and Mr. H. P. Chandler in the summer of 1901, but have not yet been completely worked up.

Only the first four of these subdivisions are discussed in the present report. On account of the brevity of the flowering season of grasses in California, of the extent of the region included within the above-described boundaries, and of its general inaccessibility and the cost of travel in a mountainous and thinly populated country, it was found impossible to visit all of the subdivisions of the region. Those portions most prominently devoted to dairying and cattle raising were therefore selected for investigation. They include a large portion of Mendocino and Humboldt counties and the narrow strip of coast line in Del Norte County.

These three are the most northerly coast counties of California, and together cover an area of about 8,513 square miles. On the accompanying map (I) their position is indicated by the dotted portion, the heavy lines nearest to it on the east and south marking the inland boundaries of the whole region of northwestern California.

TOPOGRAPHY.

In a paper on the "Geomorphogeny of the coast of northern California,[b] Prof. A. C. Lawson says of the topography of Sonoma, Mendocino, and Humboldt counties:

> The coast ranges of northern California comprise, besides the mountains proper, which, except for isolated peaks, are distant from the ocean, a broad coastal tract which may be said to be devoid of true mountain topography. This tract is clearly a dissected plateau, and impresses itself as such upon the observer very forcibly when viewed from any point not lower than its general level. (See Plate I.) The plateau is now represented only by long, roughly level-topped ridges, which are separated from one another by long, narrow valleys. At the heads of the streams which drain the valleys the ridges are frequently confluent. The ridges have a remarkable constancy of general altitude. The observer stationed on one which is slightly more commanding than the rest beholds a vast expanse of country, with no prominent profile against the sky throughout the tract in Sonoma and Mendocino counties. Ridge succeeds ridge in seemingly endless sequence, and to an observer overlooking the foreground the general effect of the ridges falling away in perspective is that of a plain. So situated he can easily imagine the intervening valleys filled flush with the crests. The plain so restored would be neither level nor even. It would be a sloping plateau of low relief. Along the front of this plateau, where it overlooks the ocean, its general

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[a] Drew, Elmer R. Notes on the Botany of Humboldt County, Cal.: Bul. Torr. Bot. Club, XVI, 147–152. 1889.

[b] Lawson, Prof. A. C.; Geomorphogeny of the coast of northern California: University of California, Dept. of Geology, Bul—241–272, Nov. 1894.

altitude is about 1,600 feet. Back from the coast, where it passes into the higher and more mountainous tract of central and eastern Mendocino County, it has an elevation of about 2,100 feet. On entering Humboldt County several sharp peaks rise abruptly above the general level of the dissected plateau to altitudes of from 3,000 feet to 4,000 feet, but remnants of plateau clearly encircle these and give their middle slopes a distinctly terraced aspect.

It is evident that northward of the fortieth parallel of latitude the forces which effected the evolution of the original plain have made but little headway as compared with the coastal region to the south of the same line, or they had been interrupted in their work by orogenic disturbances. The plain in Humboldt County represents no broad expanse, as in Mendocino and Sonoma counties, but may be followed in between an open cluster of mountain peaks and ridges. The present reconnaissance establishes the fact of its extension as far as the Bear River ridge. It doubtless extends up the coast, however , far beyond the limit set to (my) exploration.

* * * * * * *

That this great dissected plateau represents an ancient peneplain which has been uplifted from a nearly base-leveled condition to its present altitude seems beyond question. The rocks of which it is composed are of various ages, of various degrees of hardness, and have been throughout the region so disturbed that their original horizontal condition is practically nowhere to be found. The surface of the ancient peneplain consists of the beveled edges of the upturned strata. On the summit of one of the characteristic ridges of the plateau between Usal and Kenny numerous waterworn pebbles were found at an elevation of about 1,600 feet, which can only be interpreted as remnants of the stream gravels of the ancient peneplain.

CLIMATOLOGY.

The following data are compiled from the annual summaries of the Weather Bureau:[a]

The only stations within the region from which we have any climatological data are:

In Mendocino County; Point Arena and Fort Bragg on the coast, Ukiah and Cahto in the interior.

In Humboldt County; Upper Mattole, Cape Mendocino, Humboldt Light and Eureka on the coast, Hydesville in the Interior.

In Del Norte County; Cresent City on the coast.

From the interior plateau belt, proper, we have no data.

Temperature.—The mean annual temperature for the three years 1897–1899, as recorded in the annual summaries of the Weather Bureau, was 50 degrees F. The highest in 1899 was 108 degrees in the interior at Ukiah, on July 2 and other days, and 83 degrees on the coast at Crescent City on September 15. The lowest was 20 degrees at Ukiah on February 5, and 23 degrees at Crescent City on February 4.

The last killing frosts in spring were: February 5, at Ukiah; February 7, at Eureka; May 9, at Cahto; and June 19 at Crescent City. The first killing frosts in autumn occurred on October 14, at Crescent City; October 25, at Cahto; December 13 at Eureka and Ukiah.

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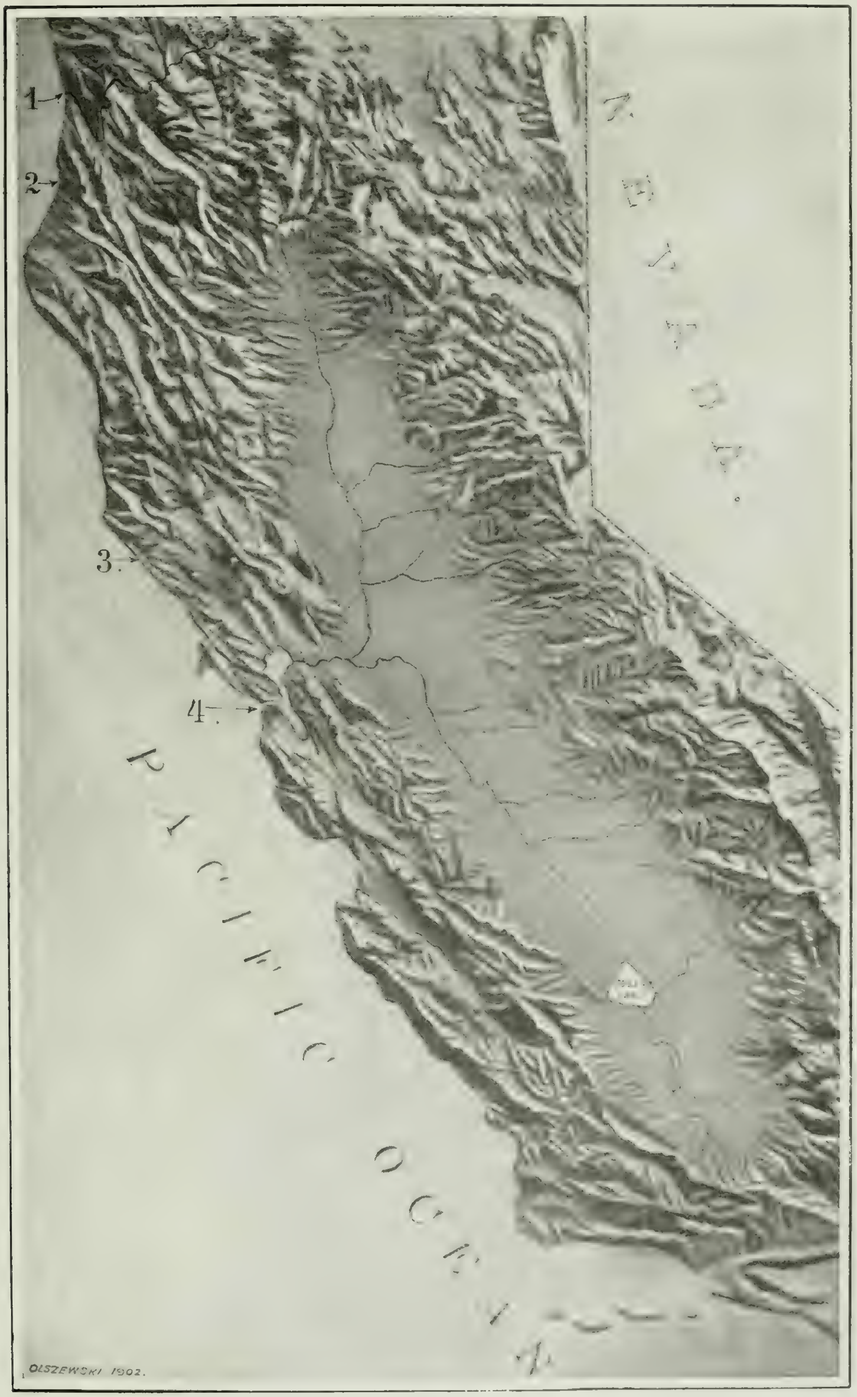
[a] U. S. Dept. of Agriculture, Weather Bureau, California Section of the Climate and Crop Service. Annual Summaries for 1897, 1898, and 1899. San Francisco.


1
2
3
4
NEVADA.
PACIFIC OCEAN
OLSZEWSKI 1902.

Topographical Map of Northern and Middle California.

The average dates of killing frosts are as follows: Last in spring, March 29 at Eureka, April 14 at Ukiah, and May 10 at Crescent City; first in autumn, November 1 at Ukiah, November 7 at Crescent City, and November 29 at Eureka.

Precipitation.—The total annual rainfall is invariably heavier in this portion of the State than in any other. Even in the drought years of 1897 and 1898 the annual rainfall exceeded 50 inches at Crescent City and 40 inches over almost the whole of Humboldt County. In 1899 the maximum was 86.55 inches at Crescent City. The following table, based upon the Government reports, shows the precipitation that may be expected each month:

Normal monthly precipitation.

Month.	Ukiah.	Eureka.	Month.	Ukiah.	Eureka.
January	7.82	7.48	August	0.01	0.16
February	5.28	6.47	September	.60	1.25
March	4.93	6.57	October	1.48	2.61
April	3.21	4.28	November	3.61	5.33
May	.92	2.99	December	6.84	7.66
June	.22	1.23			
July	.05	.10	Annual	34.97	46.13

The snowfall on the coast is usually small, 1.5 inches being reported for Upper Mattole and only a trace at Crescent City in 1898, 4 inches at the latter place in 1899, and none at Eureka. In 1898 Ukiah had 3 inches of snow, but in 1899 none. However, snow is reported to fall almost every winter on the upland ranges near Ukiah and on the plateau.

Prevailing winds.—During these three years the prevailing winds over the whole region are reported as from the northwest.

ITINERARY.

The forage conditions of this region were made the subject of an investigation by the writer, with the assistance of Mr. Walter C. Blasdale, in the summers of 1899 and 1900.

Three trips were made, of which the routes traversed are shown on Map III. The first trip occupied from May 23 to July 3, 1899, and embraced the interior plateau section. The stage road was followed from Ukiah to Eureka, a distance of about 183 miles, passing through Willits, Sherwood, Laytonville, Cummings, Harris, and Scotia. From Eureka the two mountain ridges were crossed to Hupa Valley, on the Trinity River, about 50 miles distant. From Hupa a side trip was taken to the summit of the Trinity Mountains at Trinity Summit, about 7,000 feet altitude. From Hupa Valley the descent of the Klamath River from Martins Ferry to Requa on the coast, a distance of 55 miles, was made by Indian canoe. From Requa the stage road was followed to Crescent City and Smith River, the return trip to San Francisco being made by steamer.

The second trip was taken alone and occupied from July 15 to August 10, 1899. The route followed the coast-bluff belt from the Gualala River to Kenny's, thence inland to Briceland and Garberville, and down the Eel River Valley to Ferndale. From Ferndale a trip was taken to Cape Mendocino. The return to San Francisco was again made by steamer, this time from Eureka.

A third and supplementary trip was made in the summer of 1900, this time also alone, the route crossing the redwood belt twice, the first time between Willits and Fort Bragg, the second from De Haven Creek to Branscombs. Two days were also spent in Lake County, the road from Ukiah to Upper Lake, by way of Blue Lakes, being taken, returning by way of Lakeport and Highland Springs to Hopland.

RANGE CONDITIONS.

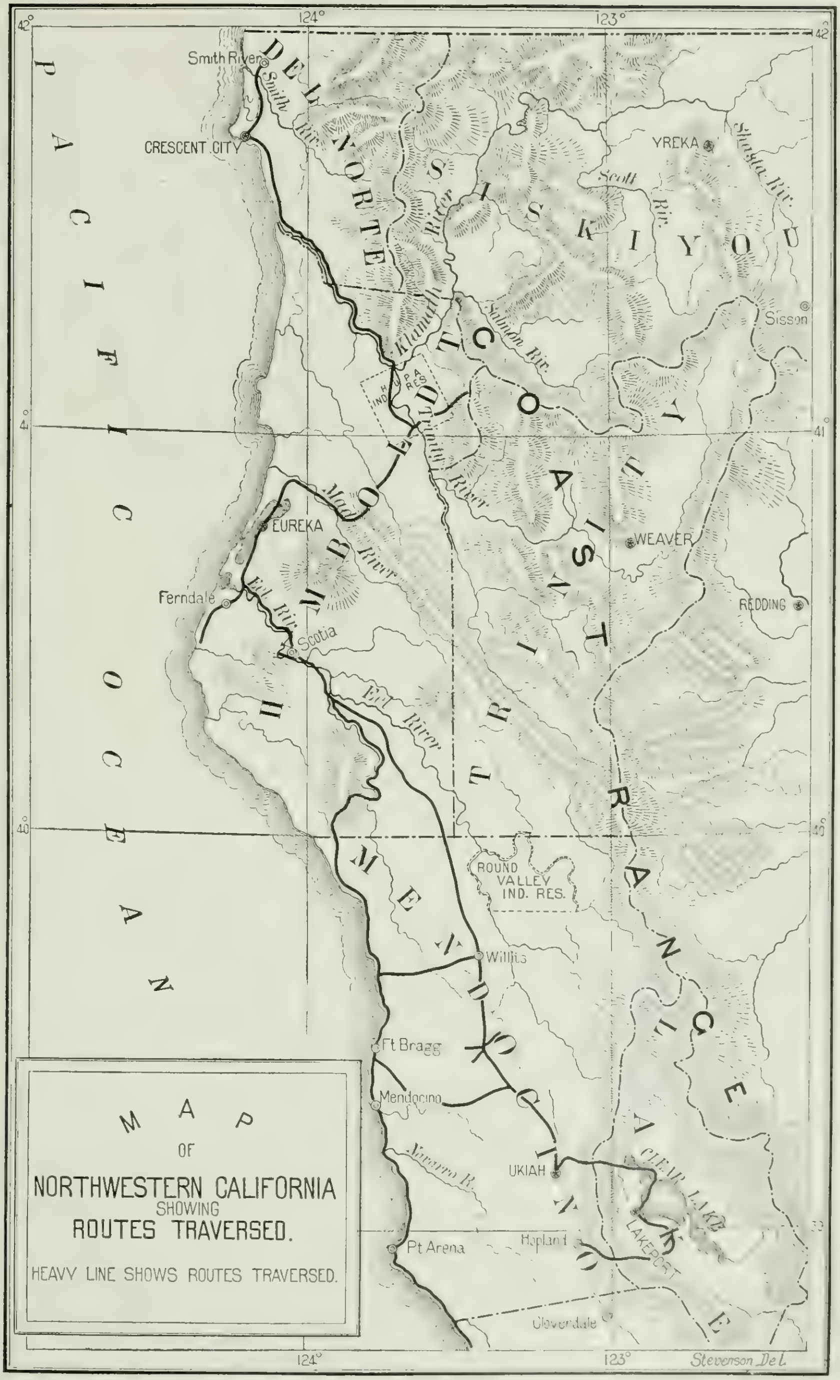
THE INTERIOR PLATEAU REGION.

MOUNTAIN VALLEYS.

Numerous mountain valleys (Pl. I, fig. 1) occur in Mendocino County, on either side of Walker Mountain, the watershed which separates the Russian River and Eel River drainage basins. South of the divide lie Ukiah, Walker, Potter, and several other small valleys whose streams run southward into the Russian River. North of the divide are Little Lake, Sherwood, Round and Long valleys, on the headwaters of Eel River. Hupa Valley is on the Trinity River, in Humboldt County. Some of these valleys lie, like glacial basins, at the headwaters of their streams; others occur a few miles lower down, at slightly lower altitudes, and are connected with the first by narrow canyons. On account of the narrowness of their outlets, some of these valleys are not infrequently flooded at the time of the winter rains. The highest have an altitude of about 2,300 feet above sea level.

Temperature.—Although intensely hot days occur at times, the climate is usually cool and humid, except, perhaps, in Hupa and Round valleys, on account of heavy summer fogs which creep up from the ocean and hang in the surrounding tree tops. Long, unbroken hot spells are almost unknown. The nights are cool. In Sherwood Valley it is said that frosts occur every month in the year. Unfortunately we have only the most meager meteorological data from this section of the region, but observation shows that the rainy season continues later into the summer than it does in the vicinity of San Francisco, and that the rainfall is probably much heavier in the former than in the latter region. A little snow falls each winter.

Water supply.—Perennial springs are abundant, flowing freely from all the higher wooded ridges. Every meadow has its own creek, which in most cases has cut a channel to a depth of from 3 to 6 feet through the soft alluvial soil. (See Pl. II.)



MAP OF NORTHWESTERN CALIFORNIA SHOWING ROUTES TRAVERSED.

HEAVY LINE SHOWS ROUTES TRAVERSED.

42°
124°
123°
42
41
40
PACIFIC OCEAN
DEL NORTE
SISKIYOU
HUMBOLDT
TRINITY
MENDOCINO
LAKE
SHASTA
COAST RANGE
Smith River
Smith Riv.
CRESCENT CITY
YREKA
Scott Riv.
Shasta Riv.
Klamath River
Salmon Riv.
Sisson
HOOPA IND. RES.
Trinity River
Mad River
EUREKA
WEAVER
REDDING
Ferndale
Eel Riv.
Scotia
Eel River
ROUND VALLEY IND. RES.
Willits
Ft Bragg
Mendocino
Navarro R.
UKIAH
CLEAR LAKE
LAKEPORT
Pt Arena
Hopland
Cloverdale
Stevenson Del.

Soils.—In Little Lake Valley and Sherwood Valley the soil appears to have been formed by delta deposition in the bed of small mountain lakes; it consists of a moist, sandy loam, which is deep, exceedingly fertile, and apparently well adapted to general farming.

The following report of analyses of soils from localities about 2 miles northeast of Willits (probably in Little Lake Valley) were made in 1891 by Dr. R. H. Loughridge, of the Agricultural Experiment Station at Berkeley.[a] The samples were received through Mr. S. F. Swortfiguer, of San Francisco, who says:

> A large part of the land from which the samples were taken lies about 22 miles inland from the ocean, and is well sheltered on the west from the coast winds by intervening ridges covered with a heavy growth of redwood timber, and from cold winds from the north by a heavy growth of pine [probably *Pinus sabiniana* or *P. ponderosa*] and fir [*Pseudotsuga taxifolia*]. The elevation is about 2,000 feet above sea level.

The samples were taken to a depth of 22 inches.

Analyses of soils near Willits, Cal.

Constituents.	No. 1459. Valley soil (Home ranch).	No. 1460. Hill soil (Hammond ranch).	No. 1461. Soil elevation 2,000 feet (Young ranch).
Coarse materials > 0.5 mm	50.00	50.00	50.00
Fine earth	50.00	50.00	50.00
ANALYSIS OF FINE EARTH.			
Insoluble matter	55.55	59.50	69.20
Soluble silica	13.56	9.33	5.57
Potash (K_2O)	.76	.61	1.14
Soda (Na_2O)	.04	.05	.09
Lime (CaO)	.29	.30	.38
Magnesia (MgO)	1.03	1.02	1.61
Manganic oxid (Mn_3O_4)	.06	.04	.05
Ferric oxid (Fe_2O_3)	8.80	12.77	5.53
Alumina (Al_2O_3)	11.95	6.97	9.74
Phosphoric acid (P_2O_5)	.04	.06	.06
Sulphuric acid (SO_3)	.04	.03	.04
Water and organic matter	7.45	9.25	6.30
Total	99.57	99.93	99.71
Hygroscopic moisture (absorbed at 15° C.)	5.27	5.89	4.47

These soils, while of excellent quality as a whole, are rather poor in lime, as compared with others of the State, though not deficient. They share with other California soils a large proportion of potash and a rather low one of phosphoric acid. The latter is doubtless the first deficiency that will make itself felt, unless it be that of humus, which (as the soil was taken to 22 inches depth, instead of 6 or 8) could not be determined in the samples.

As regards field crops, roots and not grain will hold out longest on these soils. They all contain so much gravel that cultivation will not be difficult, and roots, with fair tillage, will find no difficulty in developing. Their moisture absorption is satisfactory.

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[a] University of California Agricultural Experiment Station: Report for 1891-92, pp. 31-32; report of analyses of soils from near Willits, Mendocino County.

As to fruits, grapes, apples, and pears would seem the best suited to the soils; stone fruits will doubtless do well also, but with heavy crops will soon require fertilization with phosphates. The hill soil would seem especially adapted to peaches and high-class wines and almonds if the climate permits. Apricots should do well, especially on the Young ranch, and on the valley land if not liable to late frosting.

Judging by the large size reached by the Madroñe (*Arbutus Menziesii*) and other forest trees on these soils, a similar development and longevity may be looked for in the trees adapted to the soil, where its depth is correspondingly great. With this proviso the English walnut in the valleys, the Italian or Japanese chestnut on the hills, would be likely to do well.

Round Valley, the largest of the valleys, has an elevation of about 1,600 feet; it is said to be about 7 miles in diameter in any direction, and to contain a soil which is a rich loam, somewhat gravelly on the west side, and somewhat adobe-like on the east. It is said to be very fertile and to produce excellent crops of wheat, which, however, can at present be grown only for local consumption, on account of the inaccessibility of a good market. The valley contains about 25,000 acres of agricultural land. The rainfall varies from 38 to 60 inches per annum and the mean annual temperature is 60° F. "In 1898 the valley exported 8,000 hogs, 3,000 beef cattle, 100 mules, and 2,500 mutton sheep; it also produces large quantities of hay and an average of 150,000 bushels of grain per annum." [a]

Little Lake Valley is principally employed in grain raising, producing about 60,000 bushels annually. The average yield is said to be 20 bushels of wheat, 35 of barley, and 40 of oats.

The soil of Hupa Valley (Pl. I), an Indian reservation on the Trinity River, is very gravelly, dry, and poor. Unlike Little Lake, Sherwood, and Long valleys, Hupa is situated many miles from the headwaters of its main stream, and the soil is evidently more nearly that of a river gravel bar than of an alluvian mountain valley. It is poorly adapted to the production of agricultural crops, returning only a sparse yield of grain.

Agricultural products.—Small quantities of wheat, fruit, vegetables, and poultry are raised for local consumption. The principal export products are cattle, sheep, wool, and hogs.

Oats, of which red, black, and white varieties are grown, but principally the first named, together with a little wheat, is the principal hay crop. It is said that barley does not succeed well in these high valleys, yielding only about two tons of hay to the acre, as compared with five tons sometimes obtained in Ukiah Valley, south of the divide. Some timothy hay is grown in Sherwood and Long valleys, yielding about three tons to the acre; and red-top (*Agrostis alba*) is reported to be successfully cultivated in a few places. It is said, however, that both timothy and red-top "run out" in a few years, which may be due to the practice of pasturing too long after the rainy sea-

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[a] Ukiah Dispatch-Democrat.

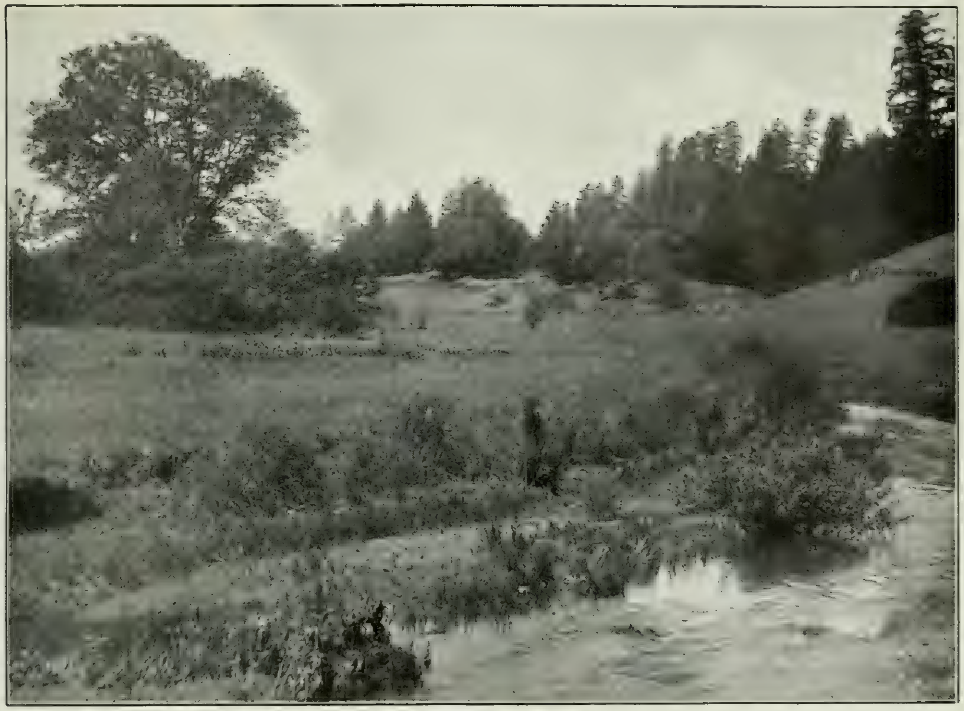

FIG. 1.—A MOUNTAIN MEADOW, SHERWOOD VALLEY.

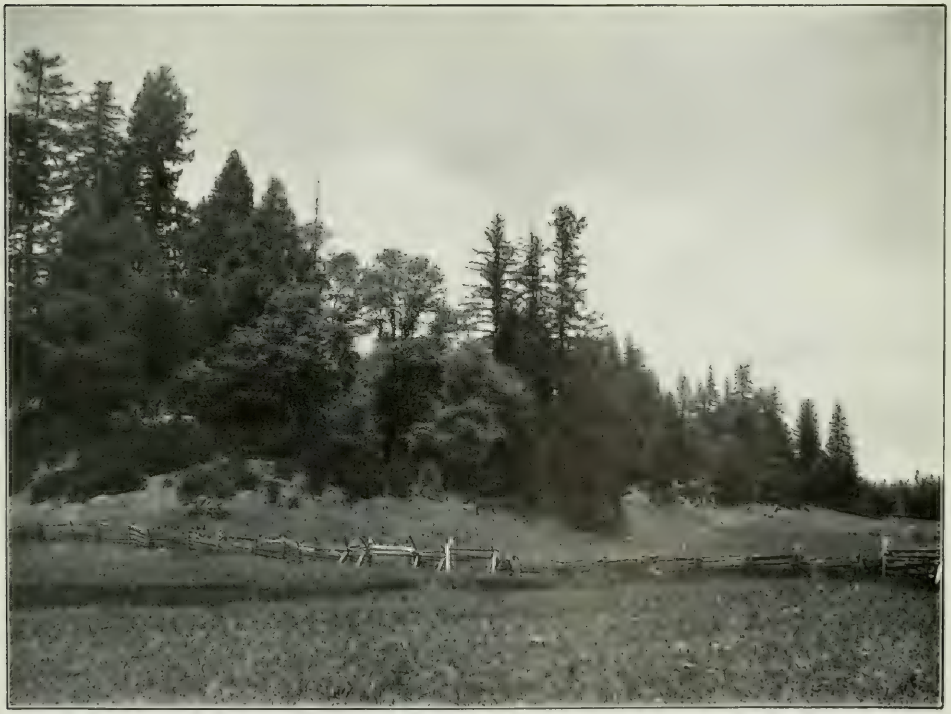

FIG. 2.—THE BORDER OF THE MEADOW.

son commences. In Long Valley it is found that stock can be fed on timothy aftermath without injury to the crop, provided they are taken off when the first rains fall.

A small quantity of alfalfa hay is produced in Long Valley. In this part of the State there is still a great deal of prejudice against it. It is considered "too soft" for either horses or beef cattle, and is fed only to cows and hogs. Much of the dissatisfaction is undoubtedly due to feeding alfalfa alone. The addition of good straw to the ration (in the proportion of one-half straw to one-half alfalfa) will make a well balanced and highly valuable feed. Moreover, alfalfa is not well adapted for pasturing, but should be soiled or fed as hay or silage. It is possible that the summer is too short in this region and the temperature not sufficiently high for the profitable cultivation of alfalfa.

The cool climate, fertile soil, abundant supply of running water and of timber for fuel and fencing, point to these mountain valleys as being ideally adapted to dairying. Nothing is done in this line, however, beyond the supply of the small local demand, on account of the distance from a shipping point and the cost of transportation by rail. From Fort Bragg, the nearest coast port, Sherwood Valley is distant about 20 miles, over an exceedingly rough, mountainous road with a descent of some 2,000 feet. The distance to Ukiah, the nearest railroad depot, is about 35 miles, the road crossing two steep mountains. A creamery has recently been started in Sherwood Valley, the output in 1899 being over 20,000 pounds, most of which went to the Mendocino Hospital. A creamery has been established in Potter Valley during the past year.

The wild meadows and pastures.—We can find no record of the condition of vegetation in these valleys before farming operations were commenced. An approximate idea of the early native flora can be gained, however, from the present vegetation of Sherwood Valley, where but little cultivation has been practiced, and where many of the meadows appear never to have seen the plow. Nevertheless, it is certain that the quantity of valuable native species has been materially reduced by heavy grazing in the fifty-odd years of occupation by white settlers, thereby increasing the relative abundance of less appreciated species. Several weedy plants have been naturalized within recent years. Mr. Sherwood, who settled in 1853 in the valley which bears his name, and who was the first white settler there, took the writer to a point some distance from his house to point out danthonia (*Danthonia californica*) as the grass which was the most abundant on hillside and valley floor and which formed the favorite and most nutritious forage plant when he first brought cattle into the valley. This grass is now scarce in the vicinity.

In Sherwood Valley the three grasses now prevalent are: (1) *Bromus racemosus commutatus;* (2) *B. hordeaceus glabrescens;* (3) *Holcus* *lanatus* (Velvet-grass, locally called "mesquite.") These three are not indigenous, but have become naturalized from Europe as weeds, and occupy the place of native plants probably of greater value.

Other naturalized species commonly met with are: Soft chess (*Bromus hordeaceus*), silvery hair-grass (*Aira caryophyllea*), small barley-grass (*Hordeum maritimum gussoneanum*), which is abundant in spots where other grasses do not thrive, and rat-tail fescue, locally called squirrel-tail (*Festuca myuros* var. *ciliata* and var. *sciuroides*). Broncho-grass (*Bromus maximus gussoni*) is occasionally met with, but at present only sparingly. If conditions prove as favorable to its development here as in the San Francisco Bay counties, however, it is likely to become a prevalent and troublesome weed. At present it is said that stock do not like it, even while young, soft, and tender, before it heads out, and after heading out its long awns are objectionable. Red-top (*Agrostis alba*) and timothy (*Phleum pratense*) have been introduced as forage plants and are occasionally met with, but have almost entirely "run out."

The only native grasses met with in the meadows are noted here. Tufted hair grass (*Deschampsia cæspitosa*) forms large tussocks and may, perhaps, be of some use for grazing, but is valueless for hay as its scattered and tufted habit of growth renders it almost impassable with a mowing machine; it is not considered of much value by the farmers. Slender hair grass (*Deschampsia elongata*) seems to occur in two or three forms. One of these is very common in wet places, and another equally abundant in drier spots. An Agrostis (*A. exarata microphylla*) is common in wettish places. Occasional specimens of meadow barley grass (*Hordeum nodosum*), danthonia (*Danthonia californica*), and prairie June grass (*Koeleria cristata*) also occur. California fescue (*Festuca californica*) is quite common along the borders of streams near the edge of the woodlands, forming large and handsome tussocks, but as a forage plant it is somewhat harsh and coarse. Two or three species of sedge and a rush are very common, but probably have little nutritive value. Blue canary-grass (*Phalaris amethystina*) occurs along the edge of the redwood forest. In the streams and swamps a species of *Pluropogon* and *Panicularia fluitans* are quite common, and slough-grass (*Beckmannia erucæformis*) is sometimes met with; the latter is reported as having been very plentiful in the sixties.

Of forage plants other than grasses and sedges the following native clovers are quite common: *Trifolium dichotomum* var., *T. microdon*, *T. barbigerum*, *T. bifidum decipiens*, *T. microcephalum*, *T. wormskjoldii* var., *T. variegatum*, and *T. tridentatum*. *T. depauperatum* and *T. longipes* var. are also met with, though only sparingly. As a forage plant, the bull clover (*T. wormskjoldii* var.) is the most valuable species, in damp places sometimes growing 2 or 3 feet high, and being a favorite food of both cattle and Indians, who eat it raw—

leaves, stems, flower heads, and all—like a salad. *T. longipes* var. forms tufts of several stems from a stout, perennial rootstock, and is worth experimental culture as a forage plant. *T. variegatum* is common in wet places and is closely eaten by cattle; it is one of the most promising native species. *Lotus pinnatus* is a common leguminous plant of wet places, and may be of some value as forage. Rib grass (*Plantago lanceolata*) has become naturalized, but is not yet abundant.

Though the various grasses, sedges, and rushes together form the largest proportion of the meadow vegetation, and native clovers are plentiful, other and less valuable plants abound, occupying space which could be filled with species of greater economic value. A buttercup (*Ranunculus occidentalis*) forms large yellow patches in the open meadow, while in marshy spots the camass (*Camassia esculenta*) produces masses of bright blue flowers in early summer. A species of *Veratrum*, not in flower at the time of our visit, is quite common, and is reported as being poisonous to stock. A species of *Orthocarpus*, with yellow flowers, is the prevalent meadow weed, and forms, together with blue-eye grass (*Sisyrinchium*) and camass, brilliant masses of color, gold and blue, in the months of May and June. Species of *Polygonum*, *Eunanus*, *Collinsia*, *Lupinus*, *Agoseris*, *Zygadenus*, *Achillea*, and *Lotus* also occur in varying abundance. Sorrel (*Rumex acetosella*) has found its way into Hupa Valley, and is met with elsewhere in the region. It is one of the most pernicious weeds.

Forage value of the wild meadows.—The composition of the herbage in these wild meadows does not give indication of high forage value; the grasses are for the most part weedy species, producing comparatively little foliage. The hay produced is poor in quality and is not eaten greedily by stock. Much of it is trampled under foot as waste. Mr. C. W. Bradford, of Sherwood, states that about 3 tons of wild hay to the acre may be considered an average yield in the valley, and that about 50 head of cattle can usually be pastured for some five months on 100 acres of valley pasture. When danthonia and native clovers were the prevalent species, the carrying capacity of meadow and pasture was probably much greater. On account of the abundant water supply and peculiar climatic condition enjoyed by these mountain valleys there are few places in the State of California which give better promise for the formation of good permanent meadows and pastures. With the evidence before us of what is actually being accomplished in the Eel River Valley, in Humboldt County, there is no apparent reason why, with the cultivation of the best adapted and most nutritious forage plants, at least 5 tons of hay per acre should not be raised, and the carrying capacity of 100 acres be raised from 50 head of horned stock for five months to 100 head for twelve months.

Improvement of pasture and meadow.—In order to produce such a desirable condition, the work of renewing meadow and pasture must be undertaken in a practical manner and one giving promise of success. The mere scattering of seed of a desirable species without preparation of soil or further attention is not likely to afford material, if any, improvement. It should also be borne in mind, in this connection, that the humidity of atmosphere and soil are important factors in the problem, and that if by the destruction of the forests and woodlands, which attract moisture, induce precipitation, and conserve the springs from which streams and rivers arise, the valleys, at present moist and fertile, are reduced to the condition of aridity met with in some other regions of the State, the chance of increasing the stock-carrying capacity will be destroyed.

To get rid of the tussocks formed by tufted hair grass and California fescue, to remove weeds, and to give the new forage plants a fair chance, the ground should be plowed in the spring to a sufficient depth to bury the turf thoroughly. It should then be allowed to summer fallow for a period, in order that the sod may rot thoroughly. The surface will require harrowing during the summer, probably several times, in order to destroy successive crops of annual weeds and to kill out the roots of perennial sedges and rushes. Sowing should be performed as early in the fall as possible, that the seed may benefit by the warm soil and the full rainfall of the growing season.

The preparation of a permanent pasture is greatly facilitated if a nurse crop of wheat, barley, or oats is grown, as it protects the young grasses during spells of north wind, frost, etc. It also utilizes the soil while the other plants are getting a start, and is of great value in keeping weeds in check. This nurse crop is preferably grown for soiling, rather than for hay or seed, as otherwise it shades the young plants of the permanent crop for too long a period and takes too much nutriment out of the soil. For the same reason only a thin sowing of grain is made, half of the usual quantity of seed being considered quite sufficient. In some places rye or wheat are considered the most desirable nurse crops. Oats occupy the ground too long, it is claimed, and are too easily "lodged" to be satisfactory.

If the plowing up of the wild meadows is considered too expensive or is impracticable, the simpler but much less satisfactory method of sowing new grasses among the old may be resorted to. In this case only about one-third of the seed required for a new pasture will be needed. The pasture must be thoroughly harrowed at the time of the first fall rains in order to preserve a seed-bed in which the new seeds can germinate.

In the East and elsewhere it is found advantageous in the preparation of a permanent pasture to sow a mixture of different species of grasses instead of only one kind, for the following reasons: Some of the best forage grasses do not make a crop until the second or even the third year; others, while in themselves valuable, do not stool-out or cover the ground completely, so that other and low, prostrate species are needed to fill the spaces between them. Some species make an early and some a much later growth; some flower early and others late, and it adds much to the value of a permanent pasture if the different species composing it mature at different periods.

A total of from 30 to 40 pounds of seed per acre is recommended for new pastures if the best results are to be obtained. It is better to err on the side of too much than too little seed; for, if the ground is not well covered at first, weeds will quickly occupy the bare spaces, and they are much harder to eradicate when once established than to keep out from the start. Experience proves that "thicker seeding more than repays its extra cost."

Forage plants recommended for trial.—Only experimental culture on the spot can finally determine which species are best adapted to any one locality or soil; nevertheless, much waste of time, effort, and expense can be avoided by studying the results already obtained from experiments conducted elsewhere. For several years the collection and study of forage plants has been made a prominent feature of the work of the Agricultural Experiment Station of the University of California, at Berkeley. These experiments have shown that, while many forage plants of great value elsewhere are not adapted to the climatic conditions of California, there are several which can be successfully cultivated.

The following list includes the more nutritious of those species which experience proves most likely to be successful: Orchard grass (*Dactylis glomerata*), reed fescue (*Festuca arundinacea*), many-flowered millet grass (*Oryzopsis miliacea*), tall oat grass (*Arrhenatherum elatius*), awnless brome grass (*Bromus inermis*), red fescue (*Festuca rubra*), rescue grass (*Bromus willdenowii*), timothy (*Phleum pratense*), meadow foxtail (*Alopecurus pratensis*), creeping bent or fiorin (*Agrostis alba stolonifera*), Italian ray-grass (*Lolium italicum*), red clover (*Trifolium pratense*), perennial white clover (*Trifolium repens*), alsike clover (*Trifolium hybridum*).

Orchard-grass has already been tried with some success between Willits and Sherwood, in shady places. It is said to start more rapidly and to make a better growth if the ground is burned over before sowing. It is grown successfully as a forage plant in the vicinity of Eureka, and has become naturalized near Berkeley and near Crescent City.

Timothy has been tried in Sherwood Valley and Long Valley, and is still used as a hay crop in some places. It is not generally liked, however, on account of a bad tendency to "run out" after a short time. This tendency is probably not inherent, however, and may be caused either by overstocking or by the practice of pasturing late, after the ground has been softened by heavy rains, a method which causes injury to the roots, especially where there is an absence of thick turf. Timothy has become naturalized in northwestern

California, at Requa, Crescent City, and elsewhere, and it is evident, therefore, that it is not unsuited to the climatic conditions of the region.

Tall oat grass, on account of its phenomenally rapid development, is useful as a nurse crop for orchard grass and other species of comparatively slow growth. Reed fescue, many-flowered millet grass, awnless brome grass, and rescue grass have been grown successfully at Berkeley and elsewhere in the State. Red fescue and creeping bent are valuable as "bottom grasses," producing a large amount of tender, succulent herbage close to the ground. Italian ray-grass and the red, white, and alsike clovers are extensively cultivated as forage plants in the Eel River Valley.

THE UPLAND RANGES.

The most extensive open ranges of the region are found in the interior, on that portion of the plateau lying east of the redwood belt, and on the adjacent mountain slopes. The long ridges into which the plateau has been eroded vary in altitude at their inland end from about 2,000 to 4,000 feet, while the peaks of the ridge forming its eastern boundary attain a height of 8,000 feet in Mount Linn and 9,000 feet in Mount Eddy.

The view from the higher ridges is extensive; on the western horizon lies the ocean as a background. In the foreground ridge after ridge, heavily clothed with timber and divided by deep, dark canyons, slope gently to the shore line, some 18 miles away. Eastward the eye wanders over bleak grass-covered ridges, brown and dry under a scorching June sun, upward to the peaks of the South Yallo Bolley, 35 miles distant, which are about 7,000 feet in height and are still capped with snow in the month of June. At the bottom of deep canyons glimpses are occasionally caught of the broad bends of Middle Fork of Eel River.

The summits of the ridges and part of their western slopes are for the most part destitute of trees and brush, but densely clothed with grass. These open slopes form what is known as the open summer or annual range. (See Pl. III, fig. 1.)

In very few places is the ground too rocky and the soil too scant and poor to furnish abundance of grass. A few such places occur, however, and are covered with a dense growth of hardy shrubs, forming what is locally known as the "chaparral" or "chamisal." (See Pl. III, fig. 2.)

The eastern slopes and canyon bottoms are for the most part thickly covered with trees and underbrush—"browse," as it is called in the vernacular. These areas form the woodland or winter range.

Temperature.—On account of the altitude and exposure of the plateau its open ridges are subject to a low winter temperature, while in summer the days are intensely hot and the nights cool. The sum-

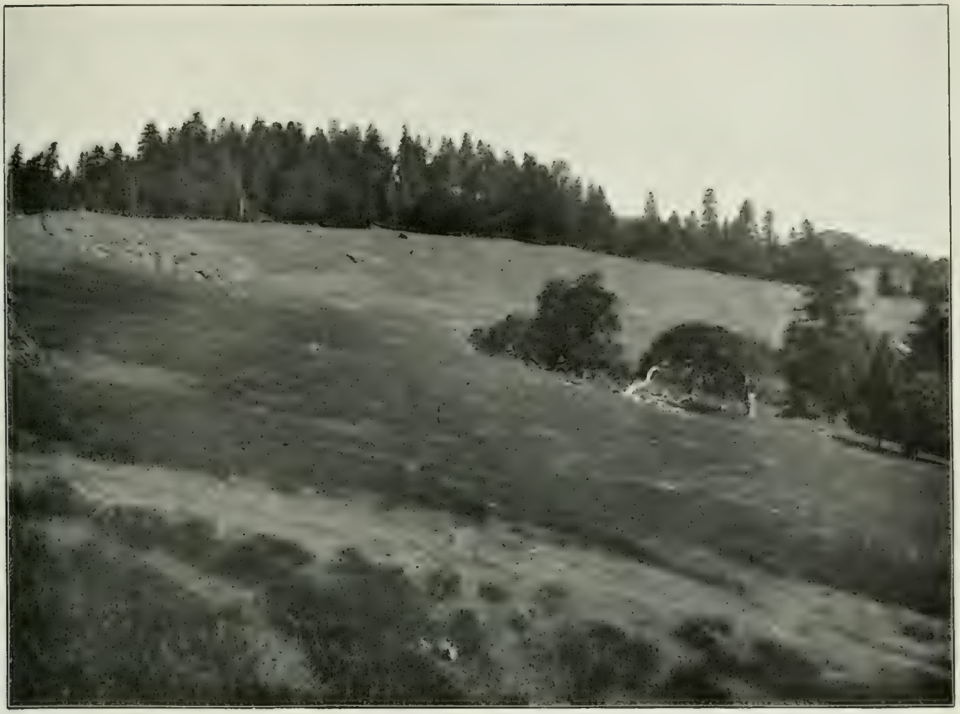

FIG. 1.—THE OPEN RANGE. SUMMIT OF THE PLATEAU ABOVE HARRIS, LOOKING EAST.

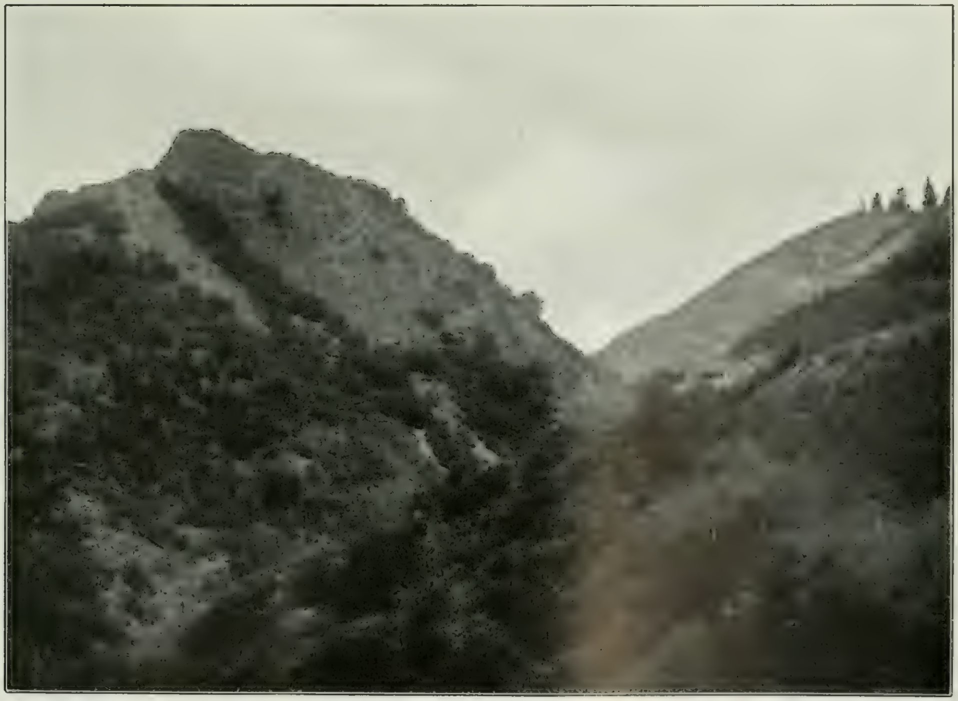

FIG. 2.—THE CHAPARRAL. WALKER MOUNTAIN, SHOWING THE STEEP, ROCKY, SPARSELY CLOTHED SLOPES, TOO BARREN EVEN FOR PASTURE.

mer temperature is not lowered, as on the coast and in some of the mountain valleys, by any sunshade in the form of banks of high fog.

Precipitation.—Over a large part of northern and middle California the rainy season, which is also the season of plant growth, commences with the latter part of September or early October and ends in April or May, varying with the year; the remaining three to five months constitute the dry or dormant season. In this particular section of the region, however, showers usually continue through May, and frequently into June, while August sometimes brings thunderstorms; in August, 1899, the rainfall varied in different localities from 0.10 to 1 inch. Mr. Bell, of Bells Springs, states that July is usually the only month in the year entirely free from rain. Mr. Tooby, of Harris, gives the mean annual rainfall at that station as about 40 inches. Reports from other points show that it is no less elsewhere, and possibly greater. Some snow usually falls on the plateau each winter. The open ridges are not subject like the coast bluffs to sea fog with its refreshing moisture.

Water supply.—Ephemeral springs are common on the ranges in the winter months, but quickly dry up with the advent of summer. Though excellent perennial springs occur here and there on the high ridges, they are usually far apart, and the dusty traveller may pass many a weary mile before finding a good camping place. Along the gulches and steep sides of the canyons, however, water is always to be found within accessible distance for stock. (See Pl. V, fig. 2). In such places the springs never dry up, doubtless on account of the protection and shade afforded by the timber and brush.

Soils.—The plateau soils consist, for the most part, of gravelly, yellow-brown, or reddish clays. A comparison of analyses of these and of the mountain valley soils is given on page 17.

From the nature of its physical conditions the upland range, which forms by far the largest portion of this section of the country, is never likely to be devoted to any other use than grazing, being unfitted for the general production of agricultural or timber crops. Whatever can be done, therefore, to improve the ranges will benefit one of the most important industries of the region.

At present the two industries of beef cattle and sheep raising are of about equal importance.

THE OPEN, SUMMER, OR ANNUAL RANGE.

As before noted, the open ranges occupy the summits and western slopes of the plateau ridges as well as the slopes of the higher mountains forming its eastern boundary.

Grasses and other forage plants.—The prevailing grasses are: (1) Rat-tail fescue, locally called "squirrel-tail" and "poverty grass" (*Festuca myuros ciliata*) small barley grass (*Hordeum maritimum gussoneanum*); (3) Soft chess (*Bromus hordeaceus* and var. *glabrescens*).

One or other of these naturalized and somewhat weedy foreign species forms the principal covering of every open range. The two first named are the most common, but as a rule they are not found in equal abundance on the same range; mile after mile is covered with small barley grass which predominates, almost, but not entirely, to the exclusion of rat-tail fescue; over another area the case may be exactly reversed, rat-tail fescue becoming the prevalent species. Both are weedy grasses, only considered valuable when young and tender; it is said that stock will not touch them after they "head out." Soft chess is considered highly nutritious when the seeds are ripe, stock eating the "heads" greedily; perhaps on this account it is less abundant than either of the others. The intermittent occurrence of the two first-named grasses may be due to their exotic origin, the species first introduced onto a range becoming the prevalent one. The fact that both are weedy grasses, and that neither one of them seems to be better adapted to range conditions than the other, nor is eaten by cattle after maturity, seems to indicate that in their case, at least, absence from certain places is not due to selection.

In addition to these three grasses the range feed is chiefly composed of alfilerilla (mostly *Erodium cicutarium*, *E. moschatum* being rarely met with), wild clovers, the prevailing species of the latter being *Trifolium bifidum decipiens*, *T. microcephalum*, and forms of *T. dichotomum*. "Bear Clover" (*T. furcatum virescens*) is common in certain situations, especially in moist "slidy" clay soils, and *T. variegatum* in moist, springy places. *T. cyathiferum* is only sparingly met with. *T. tridentatum* is especially abundant on ungrazed roadsides and ranges; its flowers have a pleasant, honey-like odor, and are very attractive to bees.

All of the above-named forage plants are shallow-rooted annuals, ephemeral in character and entirely dependent upon the opportunity to mature and scatter seed for the reproduction of their kind. Perennial herbaceous plants are not at all common, except in occasional and remote spots. The only perennial grasses noted on the dry, open hillsides were: Lemmon's bunch grass (*Stipa lemmoni*), California melic grass (*Melica californica*), a variety of red fescue (*Festuca rubra* var.), a variety of sheep fescue (*Festuca ovina* var.), danthonia (*Danthonia californica*), *Sitanion villosum*, *Elymus angustifolius*, and one or two species of *Poa*. On some of the more closely grazed ranges these perennial species are seldom seen, and occur in such small quantities as to be noticeable by their scarcity. Their rarity may be due to the fact that they are not, as a rule, turf-forming species, but tufted grasses ("bunch-grasses"), and therefore poorly adapted to withstand trampling and grazing by stock. Danthonia is reported to have been much more plentiful in former years—in fact, the most abundant forage plant, as it still is in some other parts of the State—and it is said to have gradually succumbed to sheep grazing. It is considered, par excellence, *the* "bunch-grass" of the ranges, and sometimes grows so thickly as to form an excellent turf, giving promise of usefulness under cultivation for pastures, though too short for hay. *Trifolium scorpioides*, though only locally met with, is not uncommon in partial shade, under oak trees; it has a large, subfusiform perennial root, and may prove worthy of cultivation; its flowers are fragrant with a peculiar and characteristic odor. These ranges are designated annual ranges, because the forage plants, now abundant and characteristic, are annual species of short life, in contradistinction to the perennial ranges met with more frequently in the coast-bluff section, where danthonia, tufted hair-grass, and other perennial grasses still abound.

Weeds.—With the exception of the two prevalent annual grasses, rat-tail fescue and small barley grass, weeds are comparatively rare on the open ranges north of Cummings. Annual weeds are practically restricted to a few species of *Bœri* (the genus next best represented as regards number of individuals), *Lupinus*, *Achyrachæna*, *Agoseris*, *Microcarpus*, and a few others. Hawkbit (*Hypochæris glabra*) is establishing itself in places, and is likely to cause serious injury to the range pasture. "Tacalote" (*Centaurea melitensis*) is common and very troublesome on ranges near Ukiah; its prickly "burs" are apt to decrease the value of wool. Silvery hair grass (*Aira caryophylla*) and quaking grass (*Briza minor*) are common at Elk Prairie, and fine hair grass (*Aira capillaris*) occurs on Bair's sheep range at Redwood Creek; these plants are valueless for forage, and occupy space which should be filled by useful species.

Cocklebur (*Xanthium canadense*) is reported from the Traver range, near Cummings, a few plants having been noticed in 1876, which are supposed to have been introduced with cattle from the Sacramento Valley. According to Mr. Joseph Clarke, it has been exterminated. Broncho grass (*Bromus maximus gussoni*) first appeared on the Burns place, near Cahto, in 1879 or 1880, according to Mr. Clarke; it is now spreading throughout the region. If cut before the heads mature, this grass will make good silage, and at the same time its rapid spread will be checked.

Ribgrass (*Plantago lanceolata*) has become abundant on some ranges and is said to have reduced the carrying capacity from 4 or 5 acres to 10 acres to a head.

Perennial weeds are less frequently noticed, wild sunflower (*Wyethia*) being as common as any. Sorrel (*Rumex acetosella*), perhaps the most pernicious of all perennial range weeds, has found its way into some of the ranges.

THE PRAIRIES.

The word "prairie," as used in Mendocino and Humboldt counties, may be broadly defined as any small open space among the timber, whether covered with grass or with dwarf brush. Along the coast of Mendocino County the name is applied to the areas of light, sandy "white-ash" soil covered with dwarf scrub and surrounded by timber. In the interior the "prairies" are open pastures surrounded by either timber or brush.

"Prairie" pastures usually occur in comparatively low altitudes, as on the western slopes of the hills which form the eastern wall of Russian River Valley (Pl. IV, fig. 1), where the timber is composed of oak. On Walker Mountain they ascend somewhat higher and are surrounded by brush of manzanita, deer brush, mountain mahogany, wild lilac, etc.

Around Sherwood Valley the prairies occupy the lower slopes, between the meadows and the wooded hilltops (Pl. IV, fig. 2), while in the central portion of Humboldt County they form comparatively large open clearings, several acres in extent, on knolls bordered by spruce and fir woods, as at Elk Prairie, Kneeland Prairie, and elsewhere.

Wherever these inland prairies occur the grasses and other forage plants are practically identical with those of the adjacent open ranges, of which they are simple continuations like the bays and inlets along the shores of an ocean.

THE WOODLAND OR WINTER RANGE.

The gulches and steep sides of the canyons, especially their eastern slopes, are thickly covered with trees and underbrush. Several species occur, and there appears to be little of the preponderance of one kind over another which characterizes the river bottom lands.

Trees.—The prevalent trees are: Douglas spruce (*Pseudotsuga taxifolia*); Black or Kellogg oak (*Quercus californica*), which is the largest species of oak in Mendocino County, sometimes 6 or 7 feet in diameter and with 50 feet of trunk clear of branches (Clarke); white oak (*Quercus garryana*); tan oak (*Quercus densiflora*), sometimes attaining 130 feet in height and 7 feet in diameter, one measured by the writer on the Clarke ranch having a circumference of 30 feet at 1 foot from the ground, one of its branches measuring 11 feet 9 inches in circumference at 7 feet from the trunk, and five or six limbs nearly 9 feet in circumference; Madroñe (*Arbutus menziesii*); and along the streams, pepper wood (*Umbellularia californica*). Less abundant, but by no means uncommon, are the yellow pine (*Pinus ponderosa*), chinquapin (*Castanopsis chrysophylla*), Oregon maple (*Acer macrophyllum*), and tree dogwood (*Cornus nuttallii*). The California nutmeg (*Tumion californicum*), incense cedar (*Libocedrus decurrens*), and Oregon ash (*Fraxinus oregana*) are occasionally met with, and the sugar pine (*Pinus lambertiana*) occurs on Mount Sanhedrin. The redwood (*Sequoia sempervirens*) scarcely ever grows beyond the limit of its own particular belt or isolated grove. The valley oak (*Quercus lobata*), golden oak (*Q. chrysolepis*), and other trees occur in the

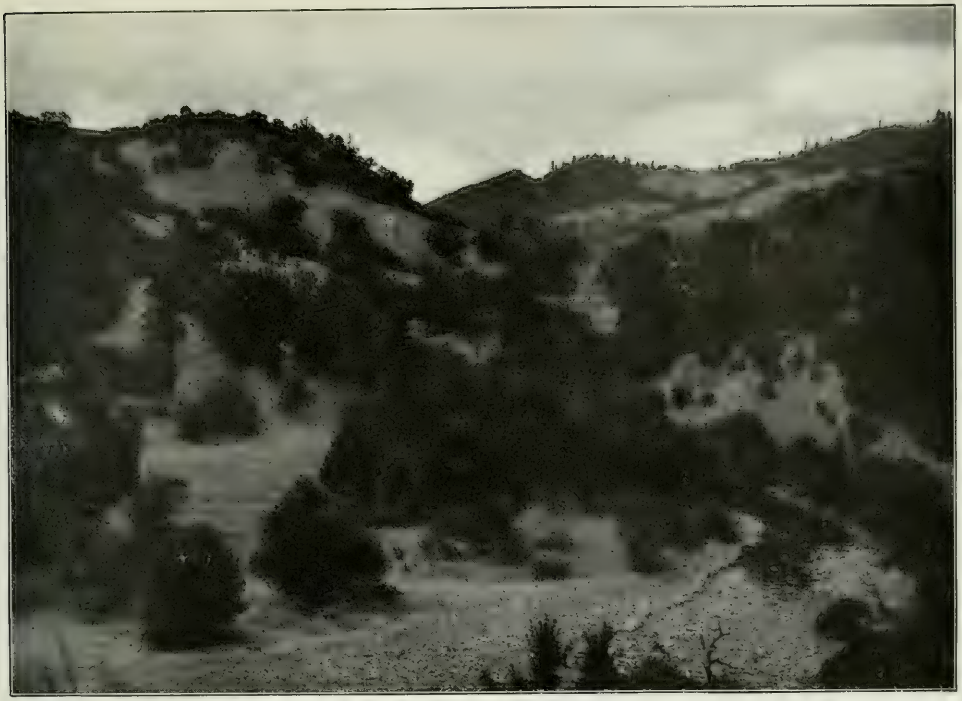

FIG. 1.—"PRAIRIE" PASTURES AT LOW ELEVATION, SHOWING THE TIMBERED CHARACTER OF THE COUNTRY. OAKS AND BUCKEYE ALONG THE RUSSIAN RIVER.

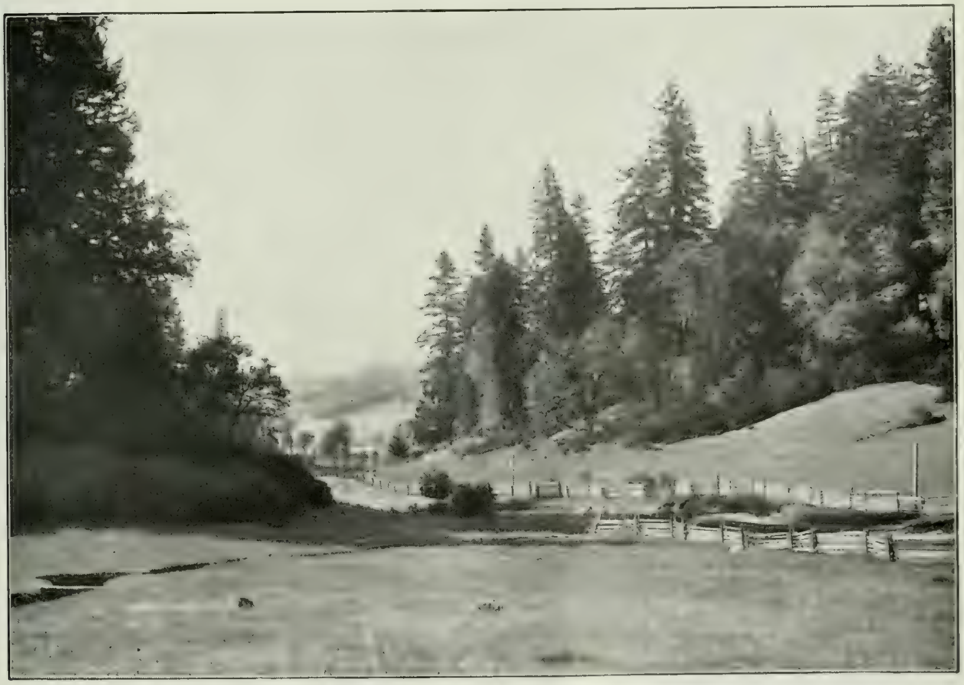

FIG. 2.—"PRAIRIE" PASTURES BELOW THE WOODLANDS, SHERWOOD VALLEY.

plateau section, but do not form a characteristic feature of the woodland.

Underbrush.—The woodland is frequently fringed with a belt of manzanita (*Arctostaphylos*). In the woods there is abundance of underbrush, in which the deer find shelter and on which they browse. It consists principally of hazel (*Corylus rostrata californica*), poison oak (*Rhus diversiloba*), cascara sagrada or pigeon berry (*Rhamnus californica*), mountain rose (*Rosa gymnocarpa*), salal (*Gaultheria shallon*), huckleberry (*Vaccinium ovatum* and *V. parvifolium*), wild blackberry (*Rubus vitifolius*), etc. In certain localities deer brush (*Ceanothus integerrimus*, *C. incanus*, and *C. velutinus*) and a species of service berry (*Amelanchier*) are found.

Herbaceous plants.—Grass species and individuals are not abundant in the shady woods, and most of those which occur have sparse foliage, affording but little feed for stock. The species most commonly met with are *Bromus lævipes*, *Melica bromoides*, *M. torreyana*, and *Trisetum canescens*. *Festuca californica*, "vanilla grass" (*Savastana macrophylla*), and *Elymus glaucus* are not uncommon.

Other perennial herbaceous plants, such as *Achlys triphylla*, *Vancouveria parviflora*, *Iris douglasiana*, *I. purdyi*, *Viola lobata*, *Aspidium munitum*, *Adenocaulon* sp., *Eriophyllum* spp., and *Brodiæa* spp. are abundant, but annual plants are comparatively rare.

Forage plants.—From off this miscellaneous assortment of plants cattle, horses, sheep, and hogs have to "rustle" a living during several months of the fall and early winter, yet they are said to keep in good condition in spite of the unpromising nature of the forage. Cattle and horses browse on poison oak, hazel, white oak, deer brush, and the few grasses they can find. Sheep freely eat, in addition to the above, the very tough and astringent leaves of the manzanita. This is shown in a striking and very characteristic manner by the neat way in which each bush is trimmed, sheep-head high, and divested of every leaf within reach.

Hogs find better picking in the woods than do other stock, and are left to run there almost the year round. They are said to live largely on the acorns of the three oaks above mentioned, on chinquapin nuts, pepper nuts (*Umbellularia californica*), madroñe, manzanita, and poison-oak berries, the bulbs and tubers of liliaceous and other plants, and on grasses and clovers. In August the manzanita berries ripen, and the hogs feed on them till the poison-oak berries, acorns, and other nuts and fruits mature. By the time these crops are exhausted the grasses and clovers are fit for food and continue till the end of June. July is the month of poorest hog feed, and it is necessary to provide corn or grain till the manzanita berries are again ripe, in August.

The acorns of the white oak are said to make the best and sweetest feed and to produce the best bacon, but the crop is very uncertain. The tan oak is the most reliable acorn producer.

Improvement of the woodland forage.—Except in portions of the redwood belt, the timber occupies land which would probably never be fit for agricultural purposes on account of either or both of the following reasons: First, the steepness of the slopes, which makes them practically inaccessible and exposes them to soil washing to a ruinous extent as soon as cleared of the protecting timber and brush; second, the poor and rocky nature of the soil. The clearing of the land would therefore be unprofitable, unless for the sake of the timber. The clearing of such lands would seriously affect the water supply of the upper ranges. This has been conclusively demonstrated near Scotia, and near Guerneville, in Sonoma County, where the clearing and keeping clear of the redwood land for pasture purposes has resulted in the drying up of many springs and small creeks which were formerly perennial. The way in which the stream beds are flooded with "waste" water from the treeless upland ranges in times of heavy rain is shown on the accompanying plate (Pl. V, fig. 1), and, by contrast, the beneficial effect of a heavy covering of timber and brush, which protects the tributary springs and creeks from evaporation, is shown in figure 2 on the same plate.

The timber produced (outside of the redwood belt) is not at present considered worth lumbering, but is used for fuel and fencing. The tan oak (*Quercus densiflora*) is highly valued for its bark, used for tanning, and an extensive industry in oak bark is carried on in the more accessible canyons near the coast. It is quite possible that the future demand for tan bark, which is becoming scarcer each year,[a] may warrant the systematic planting of the tan oak on these canyon slopes. This would result in a large increase of hog feed in the acorn season.[b]

Forage plants recommended for trial.—It is not improbable that by establishing pasture plots of shade-growing forage plants in small clearings among the timber and brush the winter feed of the wood-

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[a] Some idea of the extent of the annual destruction of tan oak can be gathered from the statement that in 1899 there were shipped 1,500 cords of bark (a cord weighing 2,300 pounds) from Point Arena and 1,500 from Greenwood; 500 cords are annually peeled at the Union Lumber Company's camps near Fort Bragg, and large amounts are annually shipped from Gualala, Iversen, Navarro, Albion, Little River, Mendocino City, Caspar, Westport, Usal, and Bear Harbor, as well as from other points. We met twenty-one 4-horse wagon loads of bark en route to Bear Harbor in a morning's drive between Kenny and Thorn.

The bark from the Greenwood lumber camps is supplied "to the California Tanning Extract Company, who have a plant in conjunction with the Greenwood mill. The bark is reduced to a liquid form, and is barreled and shipped, principally to Japan. One cord of tan bark weighs 2,300 pounds; when in liquid form it is reduced down to about 550 or 600 pounds."

[b] Acorn-fed pork is, at best, considered poor in quality, being soft and oily; it brings 1½ cents per pound less than corn-fed pork; it is claimed that even though "finished off" on corn the quality of the fat remains the same. Poland-China hogs are used almost exclusively for range feeding, being much more docile than Berkshires, which become wild and unmanageable with the freedom of the range.

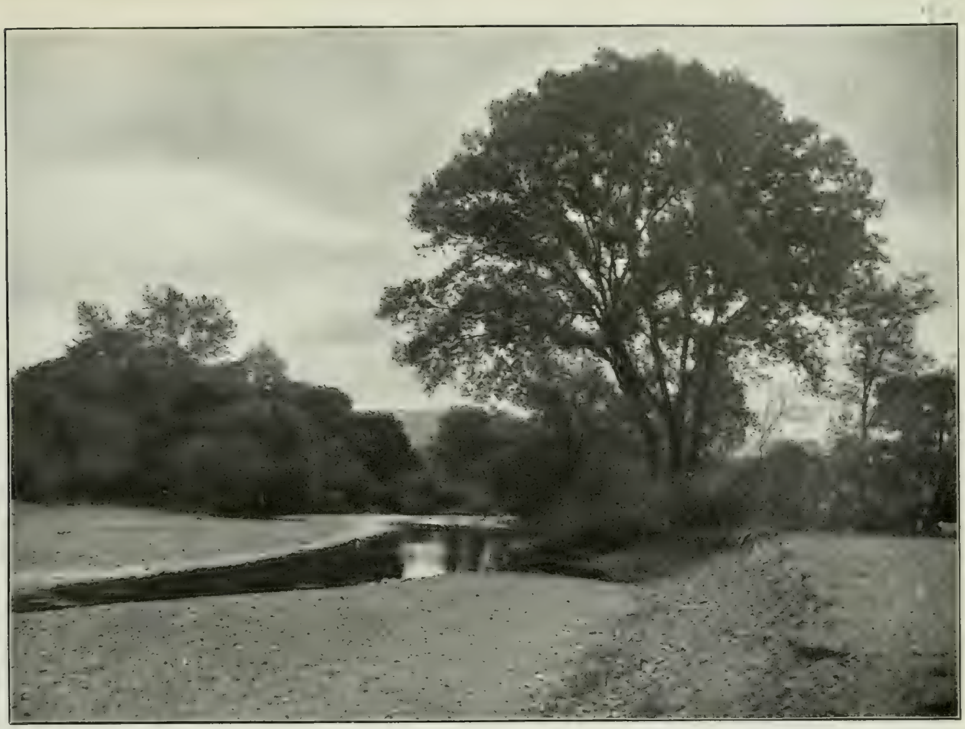

FIG. 1.—RUSSIAN RIVER, SHOWING THE EFFECT OF FLOODING, DUE TO HEAVY RAINFALL ON THE UNTIMBERED UPLANDS.

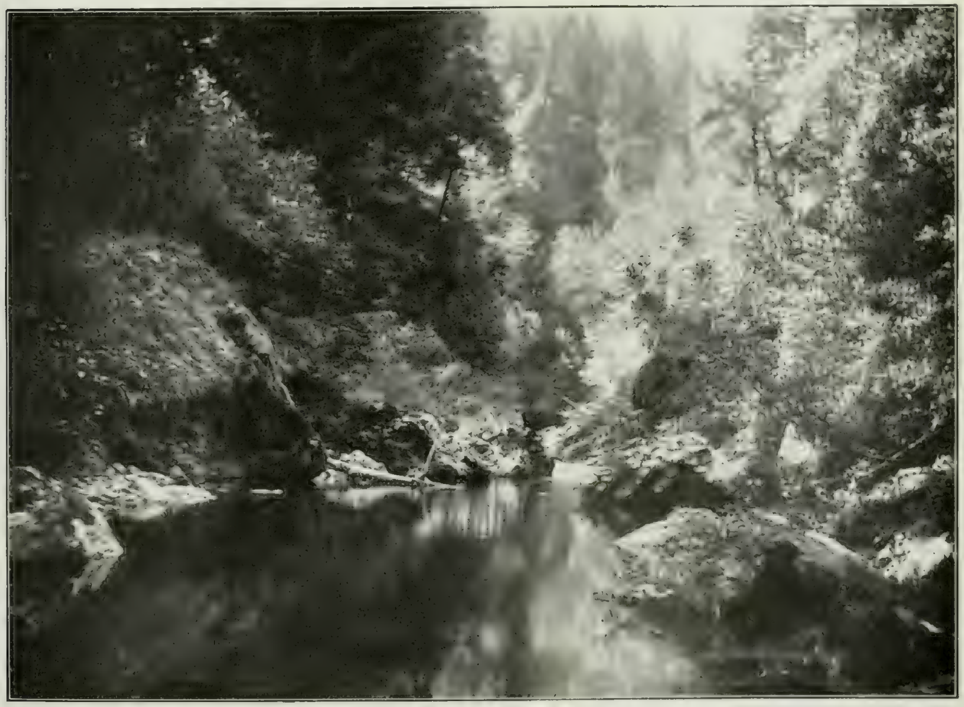

FIG. 2.—A PERENNIAL STREAM, HUPA VALLEY, PROTECTED FROM WASHING AND EVAPORATION BY TREES AND BRUSH.

land ranges could be increased. As these ranges are used for fall and early winter feeding, the grasses that will be of greatest benefit in such situations will be those that make the earliest winter growth.

Among the grasses which make the earliest winter growth at Berkeley the following are recommended for trial: Orchard-grass (*Dactylis glomerata*), tall oat grass (*Arrhenatherum elatius*), wood meadow grass (*Poa nemoralis*), reed fescue (*Festuca arundinacea*).

It must be borne in mind, however, that we can not expect to make first-class pastures out of timbered lands. It is impossible to successfully combine good timber cultures and good pastures, for the objects and needs of the two are diametrically opposed, and what will benefit the one may injure the other. The timber and brush are needed in order to preserve the flow of the springs. All we can hope to do in the way of improvement, therefore, is to somewhat increase the amount of grass produced in the open spaces.

THE CHAPARRAL.

Chaparral is the Spanish word for a thicket of low shrubs, and was used by the Spanish-Californians to designate the thickets of scrub-oak (*Quercus dumosa*) which are so noticeable a feature of rocky ridges in this region. It is now applied promiscuously to any low, dense brush of prickly or rigid shrubs growing in similar situations, as well as to the individual species of which the mass is composed. In these senses the words chaparral and chamisal are often used interchangeably; chamisal strictly means, however, a stretch of burned over chaparral, from the Spanish chamizo, a piece of half-burnt wood. The term is now generally restricted to the "chamise" bush (*Adenostoma fasciculatum*).

So local and strikingly characteristic are these chaparral areas that they have become landmarks, the word chamisal, sometimes corrupted into chemisal, chemise, or chimese, being adopted as a local name. Thus, we find on the map of Humboldt County a "Chemisal Creek" and "Chimese Ridge" in the vicinity of Harris, and a "Chemise Mountain," near Shelter Cove.

As before stated, the chaparral covers dry, stony ground, where the soil appears to be too scant and poor to support a generous herbaceous vegetation. It is usually composed of such shrubs as *Adenostoma fasciculatum*, *Ceanothus cuneatus*, *Quercus dumosa*, *Cercocarpus* sp. (mountain mahogany), species of *Arctostaphylos* (manzanita), *Garrya fremonti*, *Eriodictyon californicum* (Yerba santa), etc., the component species varying with the locality, and frequently one or other being so prevalent over a large area as to give it specific individuality.

The grasses usually met with in these arid, rocky spots are tufted in their habit of growth, and consequently come under the common category of "bunch grass." The species are few in number. *Melica* *californica*, *M. harfordii*, *Stipa lemmoni*, *Sitanion multisetum*, *S. planifolium*, *Elymus glaucus*, species of *Poa*, *Festuca*, *Bromus carinatus*, and occasionally *Festuca ovina* being the only ones collected. *Lotus americanus* and occasionally a clump of "deer brush" (*Ceanothus integerrimus*) are the only plants met with, other than grasses, which are known to be of forage value.

The individuals of these forage plants are so few and far apart as to afford only the scantiest pickings for animals, and the brush is usually so dense that stock can penetrate it only with difficulty.

Under these circumstances a piece of chaparral is naturally considered so much waste ground, being not only unproductive or almost entirely so, but, on account of the poverty of the soil, not worth the cost of clearing.

SUBALPINE MEADOWS.

In the Trinity and Inner Coast Range mountains subalpine meadows are occasionally met with at an altitude of about 6,500 feet, which resemble to a considerable extent those of the Sierra Nevada, not only in physical and climatical features but also in phytological aspect.

I had opportunity to visit a group of such meadows on Trinity Summit, to the east of Hupa Valley, between June 21 and 23, 1899, but found that it was still too early in the season to find any but the earliest spring flowers in blossom—*Salix*, *Ribes*, *Erythronium*, *Frasera*, *Kalmia*, etc. With the exception of *Melica spectabilis* the grasses and sedges which form a dense turf on the alluvial soils in hollows just below the peaks were just commencing their new growth, and in many places were still under snow. Appearances indicated, however, that here at last we had found patches of the primitive flora still almost entirely unadulterated by admixtures of alien species. The meadows are so completely isolated from the distant valleys and lower grass-covered ridges by steep rocky chaparral ridges and stretches of spruce and tan-oak forest, covering the whole of the altitudinal distance of about 6,000 feet from the floor of Hupa Valley, that it has proved difficult for aliens to cross this natural barricade. A few specimens of sheep sorrel (*Rumex acetosella*) were found in open spots along the trail, and even on Trinity Summit, being apparently the first of the alien horde to reach those grazing grounds. It will be interesting from an ecological standpoint to watch whether other species succeed in following this irrepressible and pernicious weed.

As the growth of vegetation in these subalpine meadows is later than that at lower altitudes, on account of lower temperature and consequent persistence of snow, they are valuable adjuncts to the stock ranges, providing green pasturage for several weeks after the upland ranges at lower altitudes are dry and brown.

On the plateau, where the greatest elevation does not exceed 4,000 feet and but little snow falls in winter and none remains into the summer, the grasses mature early, and there are no late alpine meadows.

SYSTEM OF RANGE ROTATION AND MANAGEMENT.

In California the season of activity in plant growth commences with the early autumn rains (September and October), while the heat rays still have power to warm the soil below the surface. It is then that the seeds of annual plants, dormant since the time of ripening in early summer, commence to germinate and the seedlings to establish themselves in the loosening soil.

Though they germinate so early in the season these annuals do not make much upward growth until the advent of the warm spring days during February or early March, after which their progress to maturity is usually rapid. By April-May or May-June, according to the season, they have attained their maximum growth and begin to ripen or are at least flowering.

The flowering season is short, and with the arrival of the hot, dry, north winds in June or July the open hillsides rapidly assume that brown and barren aspect so characteristic of a California summer.

During the fall and early winter months, when the "bands" of cattle and sheep have been reduced by summer sales of fat stock, it is customary, on ranges under the best management, to confine the stock to the woodland or winter range. This method gives the seedling annual grasses and clovers, which furnish most of the forage on the summer range, a chance to get well anchored in the soil and fairly established; otherwise, on account of their shallow rooting, a large proportion would be destroyed by trampling or pulling.

As soon as feed is sufficiently plentiful the "bands" are permitted to return to the summer range. With the advent of the dry season the animals are usually ready for market and stockmen begin to thin out their flocks and herds. A general exodus soon commences, the marketable animals being driven to Ukiah or Eureka for shipment to San Francisco.

With this exodus of sheep and cattle summer travel over the stage road from Ukiah to Eureka becomes more than ever unpleasant. The roadsides which a short time previous were carpeted with grasses and wild flowers are quickly stripped of every blade of green, and the roads, hitherto fairly good, become thick with dust, which is thrown up in clouds by the numerous droves of animals passing each day.

The reserve "bands," now much reduced in size, continue to find subsistence, and even keep fat for some time, on the ripening heads of soft chess and other forage plants which are now dried into a standing crop of short hay. This cured hay is considered highly nutritious until it has been washed by the early rains, when it seems to lose its palatableness.

In the Trinity and Inner Coast Range mountains, as well as in the Sierra Nevada, it is customary to drive the stock up the mountains to the subalpine meadows for summer pasture. For several years the Hupa Indians have followed this practice on Trinity Summit, the meadows which occur at about 6,500 to 7,000 feet altitude being a favorite range for the cattle of the reservation.

CARRYING CAPACITY.

Present capacity.—It is difficult to obtain exact data as to the present carrying capacity of the ranges, stockmen being loath to give figures for obvious reasons. The Blue Rock Range, of 2,500 acres, is said to carry 1,200 head of sheep and 100 head of horned stock, or an equivalent of an acre and a half to a sheep and 7 acres to each head of cattle. This is the same ratio for sheep as is reported for the prairies around Sherwood Valley. On the ranges near Bells Springs the maximum capacity is given as little more than an acre to one head of sheep, and 5, 6, or sometimes even 10 or 12 acres to one head of cattle. It is said that on the poorest ranges, which have become worn-out by overstocking, it takes 20 acres to support one head of cattle.

The ranges on Walker Mountain and Sherwood Mountain seem to be in better condition than those north of Cummings. Danthonia and soft brome grass are much more abundant and the maximum carrying capacity is higher (at present), the ratio being reported as only 4 or even 3 acres to one head of cattle. The latter figures may, however, apply only to open range or may include winter pasturage in the meadows instead of on woodland "browse." Such heavy stocking can not long be maintained, however. Mr. Blair, on Sherwood Mountain, has 200 acres of range and carries 60 to 80 head of hogs, 40 to 50 head of cattle, and a few horses.[a]

On the ranges which were found to be in the best condition it was learned that not less than 8 acres was allowed for each head of cattle and 1½ acres for each sheep.

Colonel Harding's range of some 13,000 acres is said to carry about 400 cattle, 100 horses, and 5,000 sheep, or a total equivalent of some 1,600 head of cattle, about 1 to 8 acres.

These ratios are supposed to include both open and woodland or brush range. It is said that there are usually about 2 acres of the latter to every 1 acre of clear land, but the proportion varies somewhat with the locality. Open range alone is said to be capable of carrying 1 head of cattle to 4 or 5 acres and 1 head of sheep to 1 acre during the season.

Former capacity.—The first white settlers in the valleys north of Walker Mountain appear to have located in 1852 or 1853, and they either brought bands of cattle with them or drove them in a year or two later, and for several years the region was a great unfenced cattle range. Humboldt County was first settled in the vicinity of Humboldt Bay in 1849 or 1850. A cattle ranch was maintained in Clear Lake Valley prior to 1849 by Andrew Kelsey and Charles Stone, who were murdered by Indians in December, 1849.

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[a] It is possible that my informant was in error as regards these figures. I much doubt whether any range in the region is as heavily stocked as this statement would indicate.

According to Carl Purdy,[a] "for years Mendocino County was a cattle county, with all the wild lawlessness which pertains to that industry and conflicting squatters' rights. As the wild animals were killed out the high price of wool stimulated sheep growing; until 1875 the mountainous country was almost entirely devoted to that branch of grazing. Then the mountain land was surveyed and landowners obtained titles, lands were fenced, and the second stage of grazing reached. The large profits in sheep raised the price of grazing lands to too high a figure, and graziers were tempted to overreach themselves by the purchase of surrounding lands." Then came a fall in the price of wool, and many rangers replaced their sheep with cattle; others, "overloaded with debts accrued by land purchases, went into bankruptcy." At present the sheep and cattle industries on the ranges are of about equal importance.

It is even more difficult to obtain information as to the actual condition and vegetation of the ranges in the first years of occupation by white people than about the present carrying capacity. There are various indications, however, pointing to a much more highly productive condition in those early days than has been realized for many years.

The fact that at the present time the three most abundant grasses are adventive species of foreign origin favors this view. There is evidence that they have become naturalized within comparatively recent years. Small barley grass and soft chess are not recorded as occurring in the State at the time of the State geological survey in the early sixties, and Dr. Bolander, who at that time was making a special study of the grasses of California, does not appear to have collected squirrel-tail in either Mendocino or Humboldt when he visited these counties in 1864 and again in 1865. It is evident, therefore, that these grasses, now so abundant, are not only naturalized aliens, but also that they must have replaced other and equally abundant species, since it is inconceivable that in such a climate fertile soil could long remain other than densely clothed with some kind of vegetation. Old-timers are unanimously agreed, moreover, that the feed on the ranges has changed materially since they first settled in the country. Mr. Bell, of Bells Springs, says that the feed on his ranges has changed several times during the twenty-seven years he has lived there, "new" (adventitious) species coming in, becoming predominant, and in their turn giving place to others.

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[a] Ukiah Dispatch-Democrat.

Colonel Harding states that small barley grass (locally called foxtail) was brought in by sheep, being observed first along their tracks.

The questions, then, arise, what were the components of the primitive vegetation which occupied the place of the present alien flora; how did it compare with the latter as regards forage value, and what new species came in, became prevalent, and then gave place to others.

The earlier floras appear to have been composed of plants more generally acceptable to stock than the weedy species now prevailing, otherwise they would scarcely have given such complete place to alien species. In other words, if they had not been highly palatable to stock they would not have been "eaten out," and if the adventive species had been equally palatable they could scarcely have acquired a foothold under the system of heavy stocking which has prevailed.

Few residents in this region are sufficiently familiar with plants to define the actual changes in the flora which take place over a period of years. Some, however, have noticed the change in composition of the range feed. Mr. Bell, Mr. Joseph H. Clarke, and others state that danthonia and other "bunch grasses," wild oats, alfilerilla, clovers, wild-pea vines (*Lathyrus* sp.), and wild sunflower (*Wyethia* sp.) were formerly the most abundant plants on the ranges. All these, they state, have been materially reduced in quantity or have disappeared altogether, and in their places squirrel tail, small barley grass, and soft chess have become established since they settled in the county. These statements are in part confirmed by Menefee, who, writing in 1873, says of this section of Mendocino County:

> The soil is * * * covered with a rich growth of clover, wild oats, bunch grass, and rosin weed or wild sunflower.

All of the above-named plants are now relatively scarce.

Wild oats and alfilerilla were not, however, the primitive forage plants, for they also are aliens, natives of the Mediterranean region, their introduction into California probably dating from the Spanish occupation. Being adventive, they too must have replaced other plants which were probably native in the sense of not having been introduced through the agency of man or his domestic animals, since we have no records of immigration earlier than that of the Mission Fathers.

On account of their wide distribution in the State, and their abundance and prevalence in the fifties, many persons have refused to believe that wild oats and alfilerilla could be other than native to the soil; even Bolander, writing in the early sixties, was inclined to believe that they must be native alike in southern Europe and California. To anyone who has watched the rapid spread of alien weeds in the rich soil and favorable climate of this State, and has observed one alien gradually give place to others, the century and a quarter which has elapsed since the Spanish occupation will appear none too short to witness the occupation of the whole State by such prolific plants as wild oats and alfilerilla, and the later disappearance of one or both of them by overstocking. This matter will be more fully discussed after the causes of range deterioration have been considered.

Col. Redick McKee, United States Indian agent, with a military party, passed over the plateau region from Santa Rosa to Humboldt Bay in the fall of 1851. Mr. George Gibbs, who kept the official diary of the party, mentions[a] that wild oats were very abundant on the slopes of the lower foothills from Santa Rosa northward. Before reaching Feliz Valley, the most northerly Spanish ranch in the Russian River Valley, he notes: "The hills passed to-day were covered with bunch grass, the wild oats having disappeared." Wild oats were again observed on what is now known as Walker Mountain, but were not noted from any place to the northward, though bunch grasses are frequently mentioned. There is no mention of alfilerilla. Colonel McKee's party seems to have been only the second white party to make the overland trip.

What then were the prevalent plant species before the advent of wild oats and alfilerilla? Though no written record appears to exist, this question can be answered in a fairly satisfactory manner by inference. It is unreasonable to suppose that in the comparatively short time (some fifty years only) which has elapsed since these hills were first ranged by white men any of the then prevalent plants could have become extinct. We must therefore look for them among the species still to be found in protected places on the ranges. In fenced-off areas surrounding some of the springs on the Bell's Springs Range and a few other places, are still to be found luxuriant growths of native clovers, grasses, and other plants which have been somewhat protected from their natural enemies, the range stock. Of course weedy grasses, with alfilerilla and wild oats, have found their way there also; but the native species have been able to hold their own to a greater extent than elsewhere. The vegetation of such places gives us a clew to the former condition of things. Here are found the native annual clovers, *Trifolium cyathiferum*, *T. bifidum decipiens*, *T. tridentatum*, *T. variegatum* var., *T. microcephalum*, and *T. furcatum virescens*, making a luxuriant growth, sometimes almost knee-deep. Sheep fescue (*Festuca ovina*), danthonia (*Danthonia californica*), *Sitanion multisetum*, *S. planifolium*, *S. villosum*, and *Elymus angustifolius*, all promiscuously known as "bunch grasses," together with "wild pea-vines" (species of *Lathyrus*) and "wild sunflower" (species of *Wyethia*), are also plentiful. In dry, rocky places California melic grass (*Melica californica*), Lemmon's bunch grass (*Stipa lemmoni*), and one or two species of meadow grass (*Poa*, allied to *P. fendleriana*) are frequently found. These are also called "bunch-grasses."

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[a] Gibbs, George: "Journal of the expedition of Col. Redick McKee, United States Indian agent, through northwestern California, performed in the summer and fall of 1851." Published in Dr. Henry Schoolcraft's Archives of Knowledge. ——: 99–177. Philadelphia, 1860.

It thus appears that these same clovers and other annual plants and the same perennial "bunch-grasses," which are now but sparingly found, were in former times the common plants of the open range, and that the species now most abundant, including alfilerilla and also wild oats, were unknown here before the Spanish occupation of California.

The following conclusions, therefore, were accepted:

1. The primitive forage plants were the "bunch-grasses" (Danthonias, Stipas, Melicas, Poas, and perennial Festucas), with annual and perennial clovers, wild pea vines and wild sunflowers; these were much more abundant in former times than now, and on account of their palatableness they largely disappeared with overstocking.

2. With the advent of white settlers and their domestic animals, wild oats and alfilerilla (*Erodium cicutarium*) took possession of the country; these increased in relative abundance as the native forage plants became scarce; as the latter diminished in quantity cattle took to eating the former until they in like manner succumbed, while other plants took their places.

3. Small barley grass, squirrel tail, and soft chess were among the next weedy introductions; the two former, when in a maturing condition being disliked by cattle, have had a chance to spread and cover the ranges, but cattle having acquired a taste for soft chess, it is being kept in check, if not diminishing, on closely grazed ranges.

4. A third immigration is now taking place, in which musky alfilerilla (*Erodium moschatum*), broncho grass (*Bromus maximus gussoni*), barley grass (*Hordeum murinum*, locally called fox-tail), tacalote (*Centaurea melitensis*), hawkbit (*Hypochœris glabra*), bur-clover (*Medicago denticulata*), and other weeds are establishing themselves along the roadsides and around ranch houses. Of these, the bur-clover, and the musky alfilerilla, have some forage value. Barley grass is eaten green in the spring before heading out, but afterwards becomes one of the most objectionable weeds for a stock range. The other aliens are destined to cause irreparable injury to the ranges unless kept in check and prevented from becoming firmly established.

RANGE DETERIORATION.

Primary cause.—Range deterioration is traceable to the desire to make as much off the land as possible, coupled with two mistaken ideas: (1) That a range can continue to carry the maximum number of stock without deterioration year after year without any rest; (2) that in order to get the most out of a range in a given period of time it must be stocked to its maximum carrying capacity.

By maximum carrying capacity is meant the highest possible number of stock that the range will turn off in good condition at selling time, without taking into account the condition of the range itself; in other words, it has reference purely to the present crop of stock, without reference to the range or to future production. The optimum carrying capacity, on the other hand, means the highest number that can possibly be carried without injury to the range, providing for the production of future crops, and eventually, therefore, bringing the best results both to range owner and occupier.

On ranges which are not stocked beyond the optimum the animals are not likely to depasture any one spot, and a sufficient number of plants of alfilerilla, native clovers, danthonia, and other bunch grasses will thus be left to ripen seed for another season's growth. Having more space over which to roam, the stock will spend less time in one place, doing less injury to the bunch grasses by their trampling. The number of stock which make the difference between the maximum and optimum carrying capacity costs more to the range owner in permanent and irreparable damage to his property than they can bring back in cash value. While every head of stock put upon the range, until the optimum is reached, is equivalent to so much additional profit, every head carried beyond the optimum not only ceases to be a source of profit, in that it limits the supply of nutritious plants both for itself and the rest of the herd, but also causes deterioration to the range. The amount of deterioration can not be measured by the actual amount of feed eaten, but increases with geometrical progression to an astonishing degree, determined by the number of useful plants left to ripen seed for the next year's crop. Looked at from this standpoint, it is evident that when an annual range begins to deteriorate the deterioration will continue at a rapid rate until checked by a change of method in management.

Stockmen all admit that overstocking is a bad practice, and condemn it; but each man has his own conception of what overstocking is, the number of acres required per head ranging all the way from 3 to 20 acres, varying somewhat, to be sure, according to the condition and situation of the range. Doubtless the point where the overstocking commences is determined, with most stockmen, by the condition of the stock, without regard to that of the range; few would realize that by running all the stock the range will carry they are actually overstocking—that is to say, seriously depleting the range and reducing the number of head which can be carried in future years.

Unlike arable land, which is cultivated and resown artificially year after year and on which the crops can therefore be cropped close without injury, a stock range has to seed itself naturally, and on account of the high mortality percentage among seeds under ordinary conditions it must be allowed to seed itself heavily or else it will deteriorate.

Excessive land valuations.—In discussing values the distinction between an annual and perennial range must be borne in mind. The annual range is much more subject to change than the perennial range; therefore the difference between maximum and optimum capacity is very much greater in the case of the former than of the latter. The value of a range, moreover, depends not alone on the number of head it will carry, but also, and primarily, upon the nature and quality of the forage. If the prevailing forage plants are annuals, or even perennial bunch-grasses, the maximum carrying capacity, for a few years at least, may be as high as a range producing turf-forming or creeping-rooted grasses, but its optimum will be much lower.

How overstocking effects deterioration.—Two factors are at work on range deterioration. One is the destruction of the choicest forage plants by selection; the other the introduction of uneatable weeds which, multiplying rapidly, crowd out the often less vigorous, useful species, and fill the spaces left vacant.

So long as there is a choice left to them, stock naturally wander over a range, picking out from among other plants the specially palatable species. Thus, by close cropping, the favorite forage plants may be almost entirely prevented from seeding. On an "annual" range most of the plants, being shallow-rooted annuals, are easily pulled out and destroyed. As they depend entirely on the production of seed for the propagation of their kind, it is clear that in this way their number is rapidly diminished. A few always escape, on account of their situation in secluded places, or because of their depauperate size, or from other causes, but these are too few in number or too poor in seed production to maintain the productiveness of the range.

On a virgin range there is not only an abundance of plants sufficient to feed all the stock and to scatter seed as well, but also a large quantity of ungerminated seed lying dormant in the soil. On this account it is clear that such a range may be stocked to its maximum capacity, for a short time, without injury. After a year or two, or perhaps a still shorter time, the granary of surplus seed is exhausted and heavy stocking prevents the formation of more than a small quantity of new seed. Then deterioration commences. Every plant eaten means not only the loss of one individual but also the destruction of so much reproductive power. Formerly there were plants enough not only for forage but also for seeding; now, every one eaten represents so much seeding capacity destroyed. And herein lies the difference in value (now represented by many dollars) between the annual and the perennial range. As an annual range depends on the production of seed for its preservation, close feeding means the destruction of the next generation as well as the present. A perennial range, on the other hand, does not depend upon seed for its preservation and often not for its reproduction; for the individual plants live on from year to year and the best of them propagate themselves from their running underground stems. Such plants can be pastured comparatively close, not only without injury but with absolute benefit, for close grazing induces them to throw out more roots and form a denser turf.

The selection by stock of the choicest of the annual plants hastens deterioration in another way. The reduction in the number of plants leaves so much more nutriment and space available for the growth of weeds and other less valuable species. Weeds invariably follow the introduction of stock into a country. By range weeds we mean any plants of thrifty, vigorous habit, which are distasteful to stock. Just as certainly as the selection by cattle of the choicest plants makes it difficult for them to maintain a foothold, so surely does the same process of selection allow the weeds every opportunity to increase, by maturing and scattering seed without let or hindrance.

These weeds are largely alien species, introduced chiefly by accident, with the advent of the white man, or along with the domestic plants and animals introduced by him at a later date. They are often plants which have become hardened to much more adverse conditions of soil and climate than they find in California, and therefore grow with greater luxuriance and spread with greater rapidity than species which have, by long continuance under uniformly favorable conditions, shown a tendency to "run out" or to deteriorate. The struggle for existence seems to be as keen among plants as among human beings, and if one species or race is killed out by its animal or other enemies, another race, less liable to attack by the same kind of enemy, steps in to fill the space. Under these conditions it is evident that on an overstocked annual range those species which are especially palatable to stock will have little chance to propagate their kind.

Wild oats and alfilerilla.—If the destruction of the most palatable forage plants by selection is constantly going on, how could such palatable species as wild oats and alfilerilla ever have become so abundantly naturalized as to be the prevailing plants on the ranges in the relatively short time since the Spanish occupation of California? And if they had at one time been able to establish themselves as aliens would not the same factor which enabled them to establish themselves prevent their being killed out by pasturing at a later date? Is it not more probable that they are indigenous species, which have suffered numerical diminution in the same way as have the wild clovers? Such are the questions asked in this connection. We are not at present prepared to answer them decisively, but to anyone who has watched the spread of introduced weeds in California, especially those from the Mediterranean region, the exotic origin and rapid increase of wild oats and alfilerilla will not appear improbable, even in the face of general range deterioration. Usually European weeds find themselves quite at home on the soil of this State, new to them, and comparatively unimpoverished. Annual species, especially, spread with great rapidity. If the wild oats and alfilerilla were introduced at the time of the Spanish occupation, when cattle were comparatively few in the land, they would have abundant opportunity to "take" the country in spite of being relished by stock. Later, however, as cattle multiplied, and sheep were introduced, forage became relatively less abundant, and at the same time weedy species, such as small fox-tail and squirrel-tail, less liked by cattle, came in, gradually monopolizing the ground left vacant by the destruction of the wild oats and alfilerilla.

Exactly the same process of introduction and eradication is taking place at the present time under our own eyes. Soft chess has, within recent years, taken possession of the hills in some parts of the State, much to the disgust of stockmen. Sooner or later the cattle have taken such a fancy to the new forage, either from necessity or choice, that it, in turn, has been almost eaten out, enough being left to show that it was once there, and other species not yet liked by cattle are taking its place.

So this process of elimination or natural selection goes on. Species which are liked by stock, but which are unable to retain their hold on the soil when grazed or trampled, disappear or become scarce, and other species come in and take their place. These, in turn, must pass away if unfitted to maintain the struggle for existence. Only the fittest survive—the fittest from the standpoint of the plant—the least fit (the weedy, useless species) from the standpoint of the rancher.

Bunch grasses.—The fact has already been alluded to that the so-called "bunch grasses" are not as well adapted for grazing as are running and turf-forming species. On account of their tuft-forming nature the former are more easily pulled out than are species which spread by means of underground rootstocks.

Sheep versus cattle.—Cattlemen think that the great depreciation in carrying capacity is due to sheep, claiming that sheep do far more injury to a range than do cattle. This is only partially true, however, and while it may be true that a range overstocked with sheep will suffer more on account of their close biting than one overstocked with cattle, which do not graze so closely, it is equally true that a sheep range carrying only the optimum number can be kept in better condition than a cattle range which carries the maximum number. Sheep do no more damage than cattle if properly handled and not crowded, and they can be kept without injury to the range; in fact, it was claimed by intelligent stockmen, accustomed to handle both sheep and cattle, that certain sheep ranges in Mendocino County were at the time of this investigation in better condition under sheep after three years of comparative drought than they were thirty years ago.

It is an indisputable fact that some men have made a financial success of sheep raising on the open range, and that at the same time their ranges are in as good condition, and in some cases better, than adjoining cattle ranges.

It is not improbable, however, that sheep do more damage than cattle to perennial "bunch-grasses."

Summary.—The cause of range deterioration, therefore, is overstocking, and it is the animals themselves that do the damage. Further, the point at which overstocking commences has not been decisively defined and varies with the individual range. What, then, can the stockman or range owner do to improve his condition? He may well say that the range is run for the sake of the stock that can be raised on it and not for the sake of preserving the feed, and that though stock may be the cause of range deterioration they can not be eliminated from the problem.

The task is only just begun, however, and the problem can not be solved immediately. In the following pages some suggestions are offered which it is hoped will prove steps toward the desired end.

RANGE PRESERVATION.

It is important to reiterate that if range renewal or improvement is to be accomplished, the practice of carrying the maximum number of stock on the range, or, in other words, of overstocking, must be abandoned. It is believed that it is possible to permanently raise the optimum carrying capacity, but it is impossible to do so while heavy stocking is practiced.

Success on one range, as compared with failure on an adjoining one, is not due to any difference in location or other range conditions, nor to any differences in the grasses or other plants composing the pasture; the natural conditions generally are, or have been, identical with those of adjacent and less-productive ranges. The secret lies in good management, and good management primarily consists in carrying the optimum number of stock and allowing plenty of grass to go to seed—to go to waste, as the majority of stockmen would call it.

Mr. J. H. Clarke and Colonel Harding, both successful stock ranchers on a large scale, are agreed in declaring that over thirty years of experience proves that this surplus grass, instead of being wasted, is equivalent to so much capital invested in the range, and is the cause of the prosperity of the few as compared with the failure or poverty of the many. Such men do not stock nearly up to the maximum. Owning their own ranges, and therefore not having to pay exorbitant interest on the capital invested, they are content with the profits obtainable from the optimum number of stock. As a result of this, they not only maintain a uniform carrying capacity without deterioration, but gain in other ways. Their wool is always cleaner and commands a half a cent a pound more than that of their neighbors, and both their mutton sheep and their lambs command a higher price. "We aim," writes Mr. Clarke, "to keep no more stock than the range will easily support. Better a superabundance of feed than a scarcity." The amount of grass to be left to seed and the optimum carrying capacity can be determined only by actual experience. Both Colonel Harding and Mr. Clarke find, however, that about 8 acres to a head of horned stock and 1½ acres to a sheep are all that their ranges can carry without injury.

Formation of a seed bed.—The advantage gained by allowing a great deal of grass to go to seed is not only the amount of seed scattered, but also the formation of a seed bed of decaying leaves and stems, which encourages germination and protects the young seedlings.

Preserve the timber and brush.—Next in importance to preservation of the forage plants is the conservation of moisture in the soil and the preservation of the water supply. The ranges which we are discussing lie along the headwaters of the main streams of the coast, and the preservation of a perennial flow of water in these streams is of as much importance to places many miles away as to the ranges themselves.

In their desire to increase the carrying capacity of the range many men commence first to clear the land of all timber and brush with a view to producing just so many more acres of pasture. Unfortunately, however, by clearing away all the brush and timber from the gulches and springs the moisture content of the soil is diminished, the available drinking water for stock is rendered less accessible, and there is probability of greater financial loss than profit from the labor expended. In the Redwood belt it is noticeable that where both timber and brush have been cleared away springs and small streams have been dried up, although the conditions for the preservation of perennial springs and streams are more favorable there than on the upland ranges. Not only is the summer water supply diminished by removing timber and brush from the headwaters of the streams, but the soil on the steep slopes washes away with much greater rapidity, owing to lack of protection from fiercely beating rains, thus increasing the depth and steepness of the canyons, which in turn facilitates the washing away of soil from the upland slopes. In Europe and elsewhere much valuable land has been ruined in this manner.

Maximum versus optimum stocking.—While it is impossible with our present imperfect knowledge of the facts of the case to determine the exact difference between the maximum and the optimum of range capacity in any case, it seems certain that a very slight reduction in size of the "band" of stock to a point below the maximum would soon make an appreciable improvement in the carrying capacity of the range and would be a step toward its renewal.

The practical stockman will naturally inquire whether the resulting gain would be worth the sacrifice of even that number of head of stock, representing just so much hard cash deducted from the annual profits of the range. If it would not, he will not be likely to take any further notice of the suggestion. In order to get as accurate an answer to this question as is possible without direct experiment, let us take a hypothetical case by way of illustration.

We will suppose that we are dealing with a range of 1,800 acres, stocked to its maximum carrying capacity, and that this maximum is

5 acres to one head of cattle, and its optimum 8 acres to one head. This range would thus be carrying 360 head of stock; reduced to the optimum, the herd would number 225, a reduction of 135 head, or 37½ per cent.

Though such a reduction seems heavy, it must be borne in mind that some of these annual ranges have naturally suffered a reduction by overstocking till it takes 10, 12, or even 20 acres to support an animal, which means that the herd has been reduced from sheer lack of feed from 360 to 180, 150 or even 90 animals to an area of 1,800 acres. This does not take into consideration the possibility of still further reduction of carrying capacity to 20 acres to a head, which is said to be sometimes the case, but which is perhaps due to very exceptional circumstances.

The question to be considered is whether it is more profitable (1) to continue stocking up to the maximum capacity of the range, with the almost certain result of a forced reduction of the herd by 50, 60, or possibly 75 per cent in a comparatively short time from lack of feed, or (2) to voluntarily reduce the herd to the optimum capacity of the range, equivalent to, say 37½ per cent reduction, with the result that this capacity can be maintained indefinitely, that the stock will be in better condition all the time, and will command higher prices than those from depreciated ranges.

A few figures may help to make the case clearer. We have no data as to the actual number of years that one of these annual ranges can continue to carry the maximum number of head without deterioration, nor do we know how long it has taken them to run down to their present poor condition. It does not seem probable, however, that it would take more than fifteen years of carrying all the stock a range can possibly feed to reduce its capacity from 5 acres to 10 or 12 acres per head.

If, for argument's sake, we take the arbitrary figures of fifteen years, and assume, moreover, that the range of 1,800 acres has been used to fatten yearlings, all of which were sold off the succeeding year and new stock purchased, the aggregate number of cattle carried in the fifteen years under the plan of stocking up to the maximum would be 3,930, and at the end of the period the carrying capacity would have been reduced from 360 head to 150 head. Supposing that this ratio of 150 head could be maintained for the next thirty years, we should have an aggregate number of 8,430 head of yearlings raised in the forty-five years.

If, however, we reduce the herd to the optimum at the outset, we should find the aggregate number raised would be 3,375 head, in fifteen years 555 head less than by the old method; but at the end of the fifteen years the herd numbers 225 instead of 150, and this number can be maintained indefinitely; in ten years more we find that the aggregate has risen to 5,625, as against only 5,430 by the maximum method, an increase of 195 head, and by the end of forty-five years the aggregate is 10,125 head, an increase of 1,695, which at a valuation of $15 per head would be worth $25,425.

Unfortunately these figures are not decisive, owing to lack of data as to the actual length of time it takes an overstocked range to deteriorate from 5 acres per head to 10 or 12 acres per head. It is hoped, however, that they will be of some service to stockmen in calling to their attention a method by which they may calculate for themselves, with the data of their own ranges before them, whether it will pay to reduce their flocks and herds to the optimum carrying capacity of their ranges.

But whether the hypothetical figures are based on correct premises or not, the accuracy of the statement can not be denied that there are men to-day who are profitably running cattle and sheep ranges on the basis of the optimum carrying capacity of the range, while their neighbors on the maximum method find it hard to make a comfortable living, and many of them have mortgaged their ranges up to the limit or have lost them through foreclosure.

RANGE RENEWAL.

The stockman whose range capacity is already as low as 10 or 12 acres per head is less interested in the difference between maximum and optimum than in the problem of range renewal, i. e., the possibility of restoring his range to a capacity of 8 or possibly 5 acres.

Though something can be done toward range renewal, probably without actually diminishing the income over a period of years, by ascertaining the optimum carrying capacity and reducing the band correspondingly, it may be found necessary, where a range is worn out, to resort to other measures to restore it to a profitable condition. In such cases a complete rest of one or even two years will undoubtedly prove highly beneficial, giving the native forage plants a chance to attain a luxuriant growth, and to produce and scatter the largest amount of seed possible, in order to reestablish themselves. Where a mortgage has been foreclosed, such a period of rest can often be accomplished while waiting for a purchaser or tenant. But to make it effective, the fences must be maintained in good condition, in order to keep out stray stock, especially horses. Some of the ranges in Mendocino County, which were lying idle during the summer of 1899 on account of foreclosure proceedings, instead of improving by the enforced idleness, suffered from the depredations of bands of stock which had either strayed there or were purposely pastured free of charge, en route to market, having gained access through gaps in the dilapidated fences. If a range is worth anything at all, it is surely worth keeping well fenced, and the cost of maintaining good fences should be as a mere trifle compared with the increment of value gained by a period of complete rest.

In many cases it may not be necessary to give the whole range a rest at one and the same time. Mr. Bentley, in his report[a] on the forage plants of central Texas, tells us that in that region, where overstocking has resulted in serious range deterioration, "some of the leading stockmen are now dividing up their holdings into several pastures, one being held exclusively for winter use, another for spring, another for midsummer or autumn. This practice will, in the case of the winter pasture, enable the early grasses to ripen and shed their seeds." Such a course may not prove as practicable or as beneficial, however, on the annual ranges of northwestern California, where the majority of the forage plants start growth together and mature at almost the same time, as it may be in central Texas, where, as Mr. Bentley says, "there is a great variety of native forage plants and grasses, comprising species that appear in succession from February to November." The practice may prove more adaptable, however, to the ranges of the coast-bluff belt.

Instead of resting the whole range at once and thereby, perhaps, missing a season of exceptionally good prices or of more than the usual quantity of feed, a portion of the range, say one-seventh part, could be fenced off and rested each year, the herd being weeded out at the same time, so that it will not exceed the optimum for the remainder of the range. At the end of seven years the rotation should be repeated, and there is little doubt that by some such method the carrying capacity could be gradually raised.

Where injurious weeds, such as tacalote (*Centaurea melitensis*) abound it will be found worth while to mow them off before they head out.

There are two questions to be answered in deciding the policy of range holding and stocking. First, is it good policy to allow the cash value of the range to deteriorate, if there is a way to prevent it? It is a true proverb which says "you can not both eat your cake and have it;" and overstocking is, as we have endeavored to prove, equivalent to living upon both interest and capital, a sure way to diminish both.

The stockman who owns his range will see the force of this point more quickly, and will be more willing to act accordingly, as far as he is able, than the renter. He will realize that as long as he can make a living off his range he can not do better than invest any surplus in improving the condition of both range and herd by weeding out and keeping the number down to the optimum. The stockman who rents his range, however, acts on a different principle. His sole object is to make the most out of the range and to invest his surplus in more stock or in other lines. Naturally he does not care anything about maintaining the value of the real estate, as it does not belong to him, and as a result the rented range usually suffers most severely.

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[a] Bentley, H. L.: A Report upon the Grasses and Forage Plants of Central Texas; U. S. Dept. Agric., Div. Agros., Bull. 10: p. 10, 1898.

This evil can be remedied to a great extent by one or other of two methods: (1) A system of long-term leases, under which it is to the tenant's interest not to materially reduce the carrying capacity, at least during the term of his occupation; and (2) a clause in the lease limiting the number of head to be carried on the range. In the latter case it will obviously be necessary to exercise great care not to sign for more than the optimum.

The second point to be considered is one which affects both the owner and the holder of a long-term lease. It is whether it is ever wise, from the point of view of personal economy, to stock beyond the optimum carrying capacity. In view of the fact already pointed out, that when once commenced the deterioration of an annual range proceeds with great rapidity, it would be poor policy to continue to carry 1 head to 5 acres, or 360 head on a 1,800-acre range, with the certainty of its reduction to perhaps 150 head in fifteen years' time, if by reducing the herd at the start to 1 head to 8 acres, or a total of 225 head, the same total profits could be obtained in a total period of twenty years and the size of the herd and the range capacity be undiminished at the end of that time.

RANGE IMPROVEMENT.

By range improvement we mean not only its restoration to its former carrying capacity, but also an improvement of the character of the range and of the quality of the feed. This is effected by the introduction of other kinds or races of forage plants.

In order to understand fully the problem of range improvement, thereby guarding against wasted effort in directions which offer little chance for success, it is necessary to appreciate the conditions which determine the character of the forage plants on a particular range.

What causes the difference between the annual and the perennial ranges of northwestern California? The perennial ranges (if we exclude alpine meadows) are found only along the coast bluffs, where the climate is relatively cool and moist in summer, owing to proximity to the ocean and the prevalence of summer fogs. It must not be supposed from this that these maritime perennial ranges keep green throughout the summer. They do, however, keep green some weeks later than the interior ranges, which feature, together with the fact that they do not deteriorate as rapidly as the annual ranges, makes them more valuable than the latter.

The annual ranges, on the other hand, are found in the interior, beyond the reach of the sea fogs. The open ridges are exposed to the full force of the scorching north winds and great sun heat during a period of sometimes eight to ten or even more weeks of absolute freedom from rain.

It is evident that the essential characteristics of good forage grasses best adapted to the dry, interior ranges are: (1) Adaptability to the peculiar climatic conditions; (2) tenacious hold on the soil, i. e., capability of withstanding trampling and grazing; (3) persistence for more than one year; (4) propagation from the roots rather than from seed.

The species which appear to best meet these requirements, and which are therefore recommended for trial on the annual ranges, are: Buffalo grass, blue grama, white clover, red fescue, sheep's fescue, hard fescue, bur clover, California lotus, and Australian ray grass.

All these species have proved suited to the climate and conditions at Berkeley, but whether or not they will be found thoroughly adapted to the climate of Mendocino and Humboldt counties can be determined only by experimental culture on the ranges themselves.

If possible, they should be planted out at the time of the first fall rains. They should in any case be carefully fenced from stock until thoroughly established. It will be advisable to sow at the same time seed of some annual species, such as soft chess, which will act as a nurse crop while the perennial species are establishing themselves.

If it is intended to sow seed in quantity, it will be wise to have it carefully examined at the time of the purchase, and only to purchase clean seed, free from seeds of injurious weeds. Some stockmen have injured their ranges almost as much as they have benefited them by the introduction of injurious weeds along with the seed of valuable forage plants.

The writer does not presume to prescribe an absolute and infallible remedy for worn-out ranges. Each range has, to some extent, its own individual peculiarities, and the man who has lived several years on the land, through divers seasonal variations, should be the one best fitted to decide how to treat that land. In matters of range renewal and improvement it is the practical and well-informed stockman himself who will have to bring the ranges back to their full carrying capacity. However, such a man is always looking for suggestions, and it is with the view of bringing them directly to his notice that these pages have been written; they are simply suggestions, and their adaptability to divers conditions must be decided by the stockman.

THE COAST-BLUFF BELT.

CLIMATOLOGY.

The climate of the belt lying immediately along the coast is more equable than that of the higher interior region; proximity to the ocean renders the winter climate milder, and snow is almost unknown, except, perhaps, on the high peaks of Cape Mendocino. In summer the prevailing northwest winds are cold and the heavy sea fogs prevent any excess of sun heat, so that even in July and August warm underclothes and an overcoat are acceptable adjuncts to a stage ride. The summer precipitation is greater here than in the interior.

This moisture of the atmosphere makes it difficult to harvest a good quality of grain hay, and oat hay, of which a considerable quantity is raised, is usually dark in color. The greater moisture also favors the development of rust, which does much damage to grain hays.

The stock ranges along the coast are limited to the narrow mesa or bench between the cliffs and the first mountain ridge which separates it from the redwood belt on the east. At Point Arena, Point Gorda, and Cape Mendocino the mesa is broader, as the redwood belt does not follow the coast line, which juts into the ocean at these points. The topography at the two latter-named places is exceedingly mountainous and the country correspondingly wild and sparsely settled.

THE MESA LANDS.

Soils.—The soils on the coast bluffs differ materially from those of the interior plateau and from those of the valleys. In many places, as on the bluffs at Point Arena and Fort Bragg, they contain a large admixture of blown sand, which renders them light and friable. Such soils are often poor in quality and unfitted for the production of good grass crops, except where they have been fertilized.

By heavy manuring every other year good crops of red and black oats are produced. The second year stock are grazed on the "volunteer" crop, or the ground is planted with potatoes, which are well suited to the soil conditions. The soil also seems to be well adapted to carrots, mangel-wurzel, and cabbages, which are grown as fall feed for cows.

These poorer sandy lands are usually characterized by growths of the dwarf native pines, *Pinus muricata* and *P. contorta.*

Between Manchester and Greenwood, and particularly on a strip of land some 3 miles long near Miller, a richer and apparently deeper soil occurs, producing splendid crops of wheat, barley, and other farm produce, and proving well adapted to the cultivation of beans and potatoes. Sweet peas, field peas, edible peas, cabbages, and other horticultural crops, in spite of the foggy summer climate, are here grown as seed crops for the San Francisco market. Some 80,000 bushels of grain and 1,500 tons of hay are reported as having been produced in this vicinity in 1899.

Grasses and other forage plants.—As before noted, perennial grasses are relatively more abundant in numbers, both of species and individuals, along the coast than in the interior. On account of the length of time occupied by the inland journey and the occurrence of an exceptionally dry season, the writer's coast trip was made too late in the season to find all the grasses in condition to collect, and the determination of some of the most important of them has therefore to be left to a future occasion.

Danthonia californica, *Festuca rubra* var., an undetermined species of *Poa*, *Calamagrostis aleutica*, *Deschampsia cæspitosa* and *D. holciformis* are the prevailing grasses, danthonia being the most abundant and often forming a dense turf of excellent pasturage. The ray grasses, perennial, Italian, Australian, and many-flowered, have been introduced and are now freely naturalized in many localities, adding materially to the value of the uncultivated forage. Soft chess is met with but sparingly.

Bull clover (*Trifolium wormskjoldii*) is common in springy places, and bear clover (*T. fucatum virescens*) on slidy, clay soils on the higher ranges; these two are considered as among the best native forage plants. White clover (*T. repens*) has become established along roadsides; bur clover (*Medicago denticulata*) and black medic (*M. lupulina*) are sparingly naturalized. Red clover (*T. pratense*) has become naturalized in a few localities.

California lotus (*Lotus americanus*) is commonly met with in dry places among brush and on the open ranges on Bear River Ridge. Rib grass (*Plantago lanceolata*) is naturalized in several places, and furnishes a small quantity of late summer feed.

A variety of red fescue forms a somewhat sparse turf on the sandy summits of the cliffs. In crevices and on ledges of the rocky cliffs *Calamagrostis aleutica*, *Agrostis densiflora*, *Poa unilateralis*, and species of *Bromus* and *Elymus* hold the soil in company with such maritime plants as *Erigeron glaucus*, *Mesembryanthemum æquilaterale*, *Lupinus michenerii*, etc.

The cooler and moister summer climate of the coast induces the forage plants to keep green two or three weeks later than on the interior ranges; they are at their best in the months of May and June. The yield of forage diminishes seriously toward the end of July, and the feeding of dairy stock with forage crops then begins. At Point Arena some dairymen commence feeding with field peas, which are fed green, following with root crops, of which carrots and mangel-wurzel are principally used. The improved strains of cattle parsnip are well worth trial in this section.

Few sheep are now run on the mesa lands; cattle are raised throughout the belt, there being a steady demand for beef in the lumber camps of the adjacent redwood region.

The high bluff lands of Cape Mendocino, from Bear River Ridge to the Upper Mattole, furnish probably the finest perennial stock ranges of Humboldt County. Danthonia forms a large part of the forage, and perennial ray grass has become established in many spots, adding much to the early winter feed. Rib grass is occasionally met with and furnishes a small amount of late feed, but it is of very little value for cattle. Our visit was made too late in the season to find the native grasses in condition for collection and determination.

Orchard grass and oats are successfully cultivated on these hills, and are used both for hay and silage, two or three silos having been built during the last two years. Several creameries are in use, the butter being carried a distance of 10 to 15 miles to the nearest railroad for shipment to Eureka, whence it is sent down to San Francisco by steamer.

The Cape Mendocino ranges are in greater need of early winter-growing grasses than of summer grasses, differing entirely in this respect from the ranges of the interior. The species which seem most likely to answer this need are: Many-flowered millet grass (*Oryzopsis miliacea*), reed fescue (*Festuca arundinacea*), Texas blue grass (*Poa arachnifera*), tall oat grass (*Arrhenatherum elatius*), Japanese wheat grass (*Brachypodium japonicum*), rescue grass (*Bromus willdenowii*), awnless brome grass (*Bromus inermis*).

THE WHITE-ASH PRAIRIES.

On the ridges which separate the smaller coast streams, e. g., the Noyo and Albion rivers, are found the "white-ash prairies," or "white plains," which are almost confined to this part of the State. They do not cover the whole of a ridge, but predominate near its western extremity where the sandstones outcrop. As its popular name implies, the soil on these prairies is white and powdery; it quickly works up into a thick dust resembling white wood ashes. It is about a foot in depth, overlaying a sandstone of very loose texture, and is said to be so impervious that after water has been allowed to stand for two weeks it scarcely penetrates more than an inch or two. A preliminary examination, kindly made by Prof. R. H. Loughridge, of the agricultural experiment station at Berkeley, shows that this soil contains a high percentage of humic acid and a low percentage of phosphates and mineral matter; the subsoil (sand) is weak in phosphates. Dr. Loughridge points out that on such soil grain crops could not be expected to live, though a few of the hardier grasses might succeed, and that liming the soil would probably improve it, counteracting the excessive acidity.

As might be expected of a soil with such marked peculiarities, it is characterized by a distinctive flora; such trees and shrubs as attain a normal height on adjacent soils become dwarfed to almost pigmy size on these white plains; the species most frequently met with are: Tan-oak (*Quercus densiflora*), Prickle-cone Pine (*Pinus muricata*), Coast Scrub Pine (*Pinus contorta*), Gowan Cypress (*Cupressus goveniana*), Chinquapin (*Castanopsis chrysophylla*), Salal (*Gaultheria shallon*), Huckleberry (*Vaccinium ovatum*), Rhododendron (*Rhododendron californicum*), Myrica (*Myrica californica*), Labrador Tea (*Ledum glandulosum*), Manzanita (*Arctostaphylos nummularia* and other species) and species of *Ceanothus*.

Sub-shrubby and herbaceous plants are also dwarfed; the following are common: *Polygala californica*, *Helianthemum scoparium*, *Xerophyllum tenax*, *Hypericum concinnum*, *Gentiana menziesii*, *G. oregana*, *Lilium maritimum*, *Panicum unciphyllum*, *Agrostis pringlei*, and *Lotus leucophæus*.

Perhaps owing to the sandy and impervious nature of the soil, sphagnum and peat swamps have formed in the low hollows on the plains, a particularly remarkable feature at such a low altitude, and especially so as neither peat nor sphagnum are known to us as occuring elsewhere in the Coast Ranges of northern California. The plants most commonly met with in these swamps are: *Ledum glandulosum* (the prevailing species), *Lomaria spicant*, *Gaultheria shallon*, *Myrica californica*, *Veratrum fimbriatum*, *Viola sarmentosa*, *Trientalis europæa latifolia*, *Sisyrinchium californicum*, *Lotus formosissimus*, *Cornus canadensis*, *Hypericum anagalloides*, *Gentiana menziesii*, *Poterium officinale*, *Phalaris cærulescens*, *Drosera rotundifolia*, *Campanula linnæifolia*, *Calamagrostis aleutica*, *C. bolanderi*, *C. crassiglumis*, *Agrostis pringlei*, *Juncus bolanderi*, *J. falcatus paniculatus*, *J. supiniformis*, several species of *Carex*, among which (according to Boott[a]) occur the following: *C. phyllomaniaca*, *C. mendocinensis*, *C. vallicola*, *C. sterilis*, *C. salina mutica*, *C. livida*, *C. polymorpha*, *C. gynodynamia*, and *C. luzulina*. The grasses are remarkably few both in species and individuals.

According to the State Survey Botany,[a] the sphagnum moss appears in the three species, *Sphagnum cymbifolium*, *S. mendocinum*, and *S. subsecundum longifolium*.

Other plant species occur on the plains and in the sphagnum swamps, but are generally less abundant or less noticeable. An analysis of the flora as above listed shows that its most characteristic feature does not consist so much in the presence of endemic species as in the commingling of the adjacent redwood and coast floras, with the addition of species commonly found in thin soils at comparatively high altitudes, and of certain peculiarly boreal species, rarely if ever found at other points in the Coast Ranges, and when met with elsewhere in the State, usually occurring at very much higher altitudes. The phenomenal feature is, therefore, the occurrence of several species belonging to high altitudes and latitudes, along a narrow coast mesa not more than 200 feet above sea level, and between the thirty-ninth and fortieth degrees of north latitude. (All the species here listed with the exception of *Arctostaphylos uva-ursi* were collected between the Navarro and Tenmile rivers).

To make this point clearer we may classify them as follows:

Plants met with on comparatively dry ridges at various altitudes in the redwood belt: *Cupressus goveniana*, *Quercus densiflora*, *Polygala californica*, *Castanopsis chrysophylla*, *Xerophyllum tenax*, *Gaultheria shallon*, *Vaccinium ovatum*, *Hypericum concinnum*, *Helianthemum scoparium*, *Rhododendron californicum*, *Ceanothus* spp., *Myrica californica*, *Arctostaphylos nummularia*, and other species.

Plants of moist, shady spots in the redwood belt: *Viola sarmentosa*, *Trientalis europæa latifolia*.

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[a] Brewer, Watson, and Gray, Publications of the Geological Survey of California, Botany, 2 Vols., 1876 and 1880.

Coast-bluff species: *Pinus contorta*, *P. muricata*, *Calamagrostis aleutica*, *Phalaris cœrulescens*, *Sisyrinchium californicum*, *Lotus formosissimus*, *Gentiana oregana*.

Boreal plants: *Cornus canadensis*, *Arctostaphylos uva-ursi*, *Juncus supiniformis*, *Hypericum anagalloides*, *Poterium officinale*, *Drosera rotundifolia*, *Lomaria spicant*, *Ledum glandulosum*, *Sphagnum mendocinum*, *S. cymbifolium*, *S. subsecundum longifolium*, *Carex vallicola*, *C. salina mutica*, *C. livida* (reported from "peat bogs and pine barrens from New Jersey and New York to Labrador and Lake Superior and high northward Alaska").

Species apparently endemic: *Veratrum fimbriatum*, *Lilium maritimum*, *Campanula linnæifolia*, *Carex phyllomaniaca*, *C. mendocinensis*, *C. gynodynamia*, *Agrostis pringlei*, *Calamagrostis bolanderi*, *C. crassiglumis*.

Attempts to cultivate the white-ash prairie lands have been made with great labor and little result. Oats, potatoes, beans, peas, corn, and cabbages will grow fairly in the best spots, and velvet-grass (*Holcus lanatus*), a little ray grass, and squirrel-tail seem to thrive; orchard grass is said to grow but poorly. Tall oat grass would probably thrive as well as the velvet grass and make a more valuable crop. Taken all in all the conditions are very unpromising for the production of agricultural crops, and it is doubtful whether the land would ever pay for the cost of clearing and breaking. Danish settlers claim, however, that it would make good farm land if laid down to some pasture grass, grazed first with horses, second with cows, third with sheep, and finally plowed and treated with all the stable manure available. The writer could not find that any one of them had tried to put this precept into practice, however, and it is at best highly doubtful whether any good pasture grass could be induced to grow there.

The native vegetation of the white-ash prairies furnishes almost as clear an indication of the physical and chemical nature of the soil as do the alkali weeds in the Great Valley Region and the Colorado Desert. The poor soils are invariably indicated by the low stature of such shrubs and trees as grow more luxuriantly on adjacent areas of good soil, particularly salal, chinquapin, cypress, *Xerophyllum*, and bracken, and the presence of labrador tea, *Lomaria*, and *Arctostaphylos nummularia*.

BOTTOM LANDS.

Alluvial lands are not commonly met with in northwestern California on account of the mountainous nature of the country. The principal alluvial areas in the coast section are the bottom lands of Eel River, with its broad flood plain, the flood plain which fringes Humboldt Bay, and the bottom lands of Smith River. A small cultivated area of bottom land occurs at the mouth of the Garcia River.

A few acres of unreclaimed salt marsh are also found at the mouths of the Noyo and Ten-mile Rivers.

Soils.—On the flood plains at the mouth of Eel River and the other streams emptying into Humboldt Bay, we find the richest agricultural soils of the region. As already pointed out these flood plains are not delta deposits, but are the result of corrasion of the rocks of the wild-cat formation. Until within recent years they have been subject to tidal inundation, but a large portion has been reclaimed from the ocean by means of embankments. There still remain large areas of unreclaimed salt marsh, however.

The fertility of these bottom lands is a source of constant wonder to those unacquainted with the prevailing conditions. To quote again from the Pacific Rural Press:

> Mr. A. Kansen, of Ferndale, keeps 35 cows on 34 acres, secures an average yield of 300 pounds of butter, and buys no feed whatever. The cows are on pasture nine months of the year, and for the other three are fed hay and roots, all grown on the 34 acres. J. E. Brown, also of Ferndale, keeps 35 cows on 40 acres, his average yield and feeding being like the preceding. These records are strictly credible when one knows the natural pasturage conditions prevailing and the favoring climate for the growth of supplementary succulent food supplies. The cows are simply good selected grades of dairy breeds. The average in the dairy sections of Humboldt County—that is, on the best of the valley lands—is said to be 1½ acres to the cow.

Forage crops.—The principal forage crops are red clover, oats, and Italian ray grass for hay, peas, and a little corn for soiling, and mangel-wurzel (locally known as "beets") and carrots for root crops. Some alfalfa is now grown both for pasturage and hay, and barley for ensilage. Stock are frequently pastured on red clover. Dutch clover has taken possession of many of the pastures.

Red clover is considered by far the best and most productive crop, but farmers complain that after some years of successful growth it "runs out" and can not readily be started again. As Professor Hilgard has repeatedly pointed out to them, this is undoubtedly due to excessive acidity of the soil, induced by lack of lime, and can doubtless be remedied by liming. A deposit of lime has been found on Jacoby Creek, between Eureka and Arcata, which promises to solve the difficulty and to render the continued successful cultivation of red clover a possibility. The following method of treatment is recommended by Professor Hilgard, who writes to the Eureka Watchman, as follows:

> Relative to the amount of lime to be applied to your sediment lands I would say that half a ton is about the minimum from which you can expect any prompt results, and from 1 to 2 tons is the usual gauge in such cases. However, the best amount varies materially in different lands; and, as yours contains so little clay, I should say the smaller dressings might be adequate if repeated, rather than using at once the 4 or 5 tons commonly prescribed in the old country.
>
> The way they use it there is to haul it in piles, let the rains slake it, and when dry enough spread with shovels, much as you would stable manure; then harrow or cultivate in; but any way to spread it uniformly will do. It can be made into

whitewash and filtered from a cart tank, as is commonly done in Holland. It should not be allowed to air slake, as in that case it loses some of its efficacy, and its action becomes slower. Of course it should be understood that quicklime will injure seeds and plants with which it comes in direct contact. It should be applied on the bare soil, and is especially useful if put on top of a green manure crop or sod turned under. After a few weeks it becomes sufficiently mild to be innocuous to seeds unless applied in very large amounts. In the case of orchards or vineyards small successive doses—say half a ton to the acre—are preferable to heavy applications.

Complaint is also made that it is difficult to get a good stand of red clover on newly plowed land. This difficulty can be largely overcome by sowing Italian ray grass and red clover together. The grass serves as a nurse crop for the clover, increases the yield of hay during the first two years, and gradually "runs out," leaving a good stand of clover.

Land values.—While upland grazing lands in large tracts vary in price from $4 to $15 per acre, according to location, carrying capacity, etc., the rich bottom lands of the Lower Eel River Valley, near Arcata, and at Salmon Creek, Elk River, and Jacoby Creek are held at from $75 to $300 per acre, according to location and state of improvement.[a] Well-improved farms, fully seeded to red clover, pay good interest on the latter sum. The best farm lands near Ferndale are said to command $500 per acre, and are hard to obtain at the price.

SAND DUNES.

Dunes of drift sand of greater or less extent are found throughout the California coast. Wherever they occur they prove detrimental to agricultural interests, not only representing so much waste land which might otherwise be utilized, but surely, even if slowly, spreading, and sometimes completely ruining what might have been the best of farm lands. On account of the slowness of their encroachment, however, farmers and landowners are often indifferent to the damage being done.

The principal sand dunes of the coast of northwestern California occur at the following points:

At the mouth of the Garcia River at Point Arena, on the Sheppard Ranch. Though not extensive at this point, they are steadily encroaching on the limited area of rich river-bottom land, and have already done no little damage.

Between Pudding Creek near Fort Bragg and the mouth of the Tenmile River, some 10 miles north, occur the worst cases on the whole of the coast area which came under our observation. At Inglenook it is said that the dunes have encroached on good farm land to the extent of 500 feet in two years. At Cleone a half acre of orchard has been ruined, the trees having been almost wholly covered with sand in four years' time. A ranch house has had to be moved and the

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[a] Resources of California, San Francisco, September, 1900.

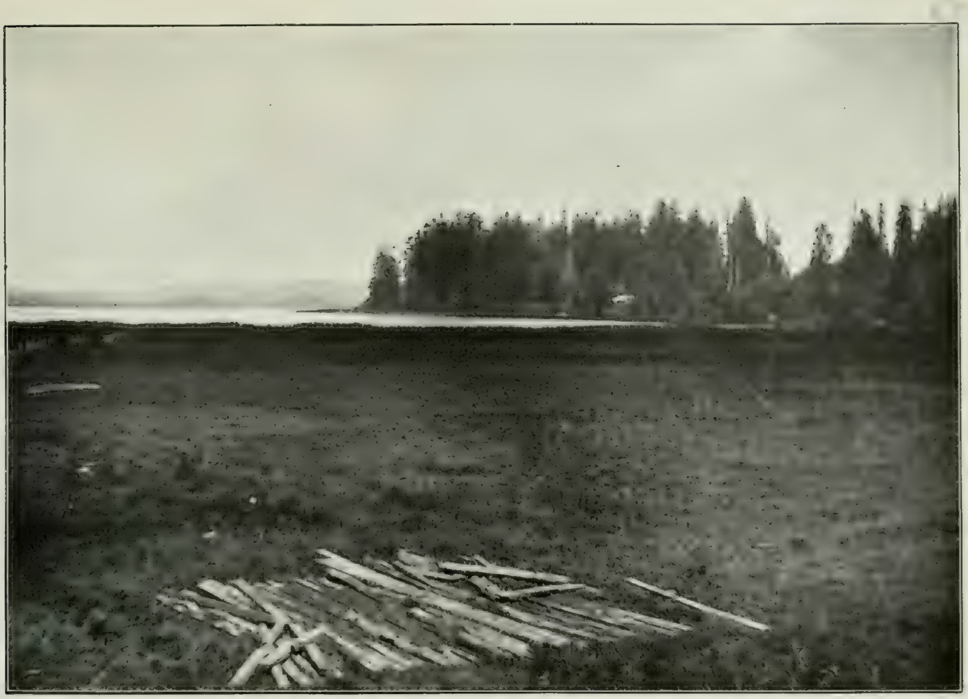

FIG. 1.—A LAGOON AT CRESCENT CITY, CAUSED BY DRIFTING SAND, WHICH HAS FLOODED A LARGE AREA OF PASTURE LAND.

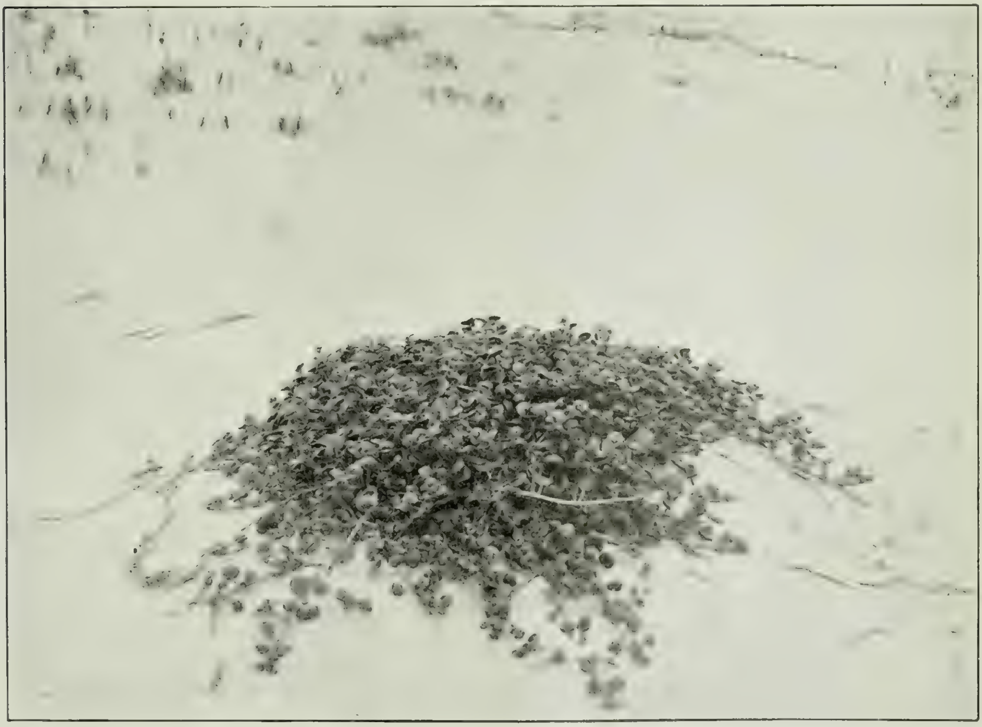

FIG. 2.—YELLOW SAND-VERBENA (ABRONIA LATIFOLIA), OF SOME USE AS A SAND BINDER.

county road diverted in order to avoid the dunes, which at this point are of great size.

At Eureka the peninsula which almost incloses the harbor (see Map III) is chiefly composed of sand dunes, which do not, however, encroach on the mainland, though possibly doing some damage to the harbor itself by silting up the channel.[a]

The conditions at Humboldt Bay are described in the following extract:[b]

> Humboldt Bay is 14 miles in length and from one-half mile to 4 miles in width. It has a tidal area of 28 miles and 35 linear miles of navigable channels. It is situated near the center of the coast line of Humboldt County and extends nearly parallel therewith, being separated from the ocean by two narrow peninsulas of sand. Being so completely landlocked, this harbor is of the utmost importance to a coast so barren of good harbors as is the Pacific; but its usefulness has in the past been seriously impaired by shifting sand bars, which obstructed its entrance, and by the shallowness of some of its inner channels. In 1889 the General Government began improving the entrance to the harbor by extending two jetties of rock, one on each side of the channel, so as to confine the waters to a permanent way. This work was completed in September, 1899, at a cost of more than $2,000,000.
>
> Eel River for a few miles of its lower course is navigable for small vessels, and has at several periods had regular steamer connection with San Francisco; but its navigation is often interrupted by the formation of sand bars at its mouth.

At Crescent City the mouth of a creek has been completely closed by drift sand, forming a large lagoon (Plate VI, fig. 1) and causing the winter flooding of extensive grazing lands. The protection afforded by a native pine forest appears to have prevented the encroachment of sand on the farm lands at this point. Should this timber be cut at any time for fuel, which is likely to be done as population increases and fuel becomes more scarce, a large tract of dairy land would be jeopardized. Precautions should be taken against such a result.

Big Lagoon, at the mouth of Maple Creek, Humboldt County, may perhaps have been formed in the same way as the lagoon at Crescent City.

Native sand binders.—The following native plants grow naturally on the sand dunes, and act to a greater or less extent as sand binders:

Abronia latifolia (yellow sand verbena) (Plate VI, fig. 2) is common at the mouth of the Garcia River; of some value as a sand binder on account of its heavy, prostrate stems and large, flat leaves, but not the best plant for the purpose, as it does not root at the nodes, and oftentimes the sand is blown away from beneath the branches, leaving the large, fusiform roots exposed to wind and sun.

Arctostaphylos uva-ursi is a prostrate species, forming large mats on almost pure drift sand on the sand spit opposite Eureka, where it becomes a valuable sand binder, rooting from the nodes. It fruits freely in such situations, readily producing its kind.

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[a] Since the above was written complaint has been received by the writer of serious injury to lumber mills caused by the drift sands at this point. Reclamation work has already been started by the planting of beach grass.

[b] "Resources of California."

Bromus, sp., is a common grass on overgrown, sandy land at Samoa, near Eureka, helping to bind the drifting sand.

Convolvulus soldanella is not uncommon on the sand dunes, growing in almost pure sand, but apparently of little value as a sand binder, as it does not mat on the surface; the sand freely blows away from between the plants.

Corethrogyne californica obovata is a common species on the sand hills at Samoa, near Eureka, but of little economic value.

Elymus sp. grows luxuriantly in drifting sand at Samoa, making a promising sand binder. It is said to be eaten by stock while young and until about 14 inches high, when it becomes too coarse for forage.

Festuca rubra var., grows luxuriantly though not abundantly in drifting sand on the sand spit opposite Eureka. It might be used with advantage in company with *Poa douglasii*, as the one would to some extent complement the other. It also gives promise as a forage plant, but we have no data as to its actual forage value. At Samoa this variety seeds very freely, a quality lacking in many of our sand binders.

Juncus sp. is common in loose sand on the sand dunes of Humboldt Bay.

Poa douglasii (Sand-grass) is thoroughly at home in the drifting coast sands from San Francisco northward, but on the California coast is of little use as a sand binder, being too sparse in its growth to cover the surface, and too short of stature to check the drifts, which blow right over it, or out from under it, leaving the roots bare; these when exposed quickly dry out and die. In company with the variety of *Festuca rubra* mentioned above it might be used to advantage, as the one species to some extent makes up for the deficiencies of the other.

Tanacetum camphoratum is a common species on loose, drifting sand at Point Arena and Humboldt Bay.

Salix sp., a species of willow, is also common in some places, and at Inglenook has been planted as a check hedge, but with only partial success.

Elymus arenarius (Rancheria grass) occurs in sandy soils on Drakes Bay and Point Reyes, but was not collected within our limits. Though too sparse in growth to be of much value if used alone as a sand binder, this grass will doubtless prove serviceable if planted in company with other species.

Lupinus chamissonis (Blue lupin) is commonly met with from Point Arena southward and is of some use as a sand binder. The yellow tree lupin (*L. arboreus*) was not found north of Point Reyes. *Collinsia bartsiæfolia* occuring in drift sand near Cleone is an annual plant. Several other plants of lesser importance grow on the sand dunes.

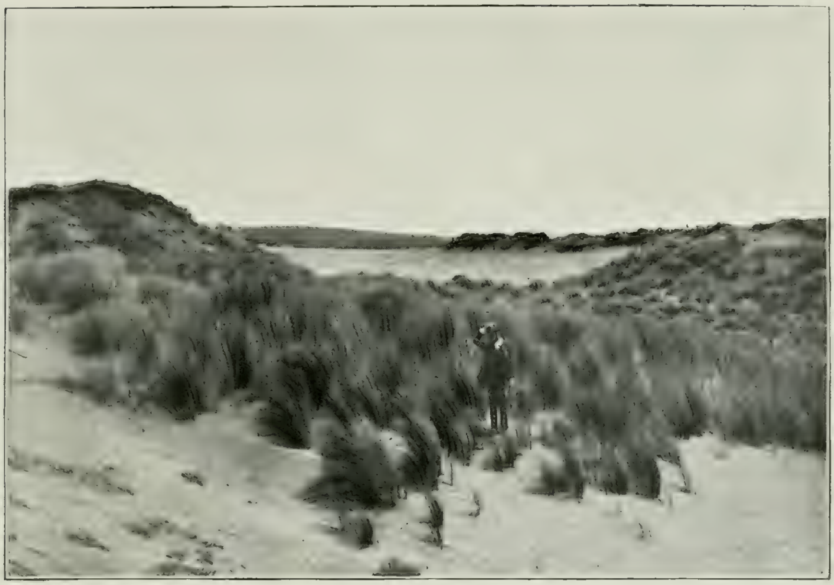

FIG. 1.—BEACH GRASS AT POINT REYES, CAL.

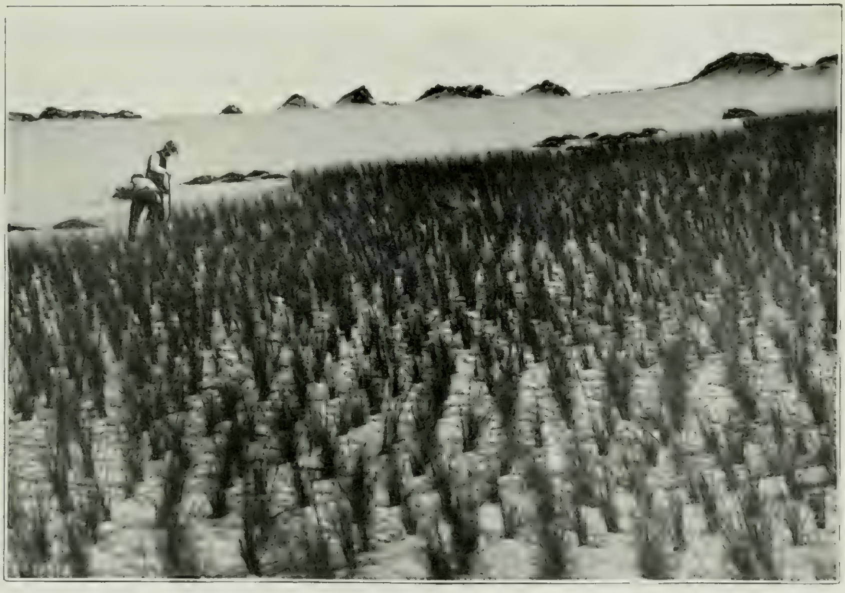

FIG. 2.—PLANTING BEACH GRASS AT CAPE COD, MASSACHUSETTS.

Methods of preventing drifting and reclamation of waste dunes.—Although the above-named and other native plants grow freely on the dunes, no one of them proves thoroughly satisfactory as a check to sand encroachment. Almost all of these species grow so slowly and so sparsely as to allow the sand to blow away from their roots, which die on exposure. They are, moreover, too dwarfed in stature to check the drifts successfully. Therefore, if the drifting is to be checked and the waste dune areas are to be made useful, it is necessary to remedy this defect. The first point to be gained is to render the surface as nearly stable as possible, in order that useful plants may have a place on which to grow. For this purpose the cultivation of certain selected sand-binding plants has been adopted, in Europe and in the Eastern States, as being the cheapest and most satisfactory means of checking and reclaiming drift sands. The following are considered the most satisfactory sand binders:

Beach grass (*Ammophila arenaria*) (Plate VII) was introduced at Point Arena some ten years ago by Mr. Sheppard, a few plants having been obtained from the commissioners of Golden Gate Park, San Francisco, who had successfully used it at that place (Pl. VIII, fig. 2).

It has thriven admirably at Point Arena, and now covers about an acre of the dunes. This grass is by far the best sand binder tried on the California coast, its dense growth, long under-ground stems, and long tufts of leaves preventing the sand from blowing away from the roots. Moreover, the banking up of sand does not in any way injure the plant, which continues to lengthen its stem and throw out new roots as fast as the sand piles up around it. Professor Scribner states that "a plant will, by gradual growth upward, finally form stems and roots sanded in to the depth of fully 100 feet."

Beach grass is most successfully propagated by transplanting in the autumn. Vigorous plants are selected and pulled up by hand. Usually a bundle of half a dozen plants is held together by one man, while another makes a hole in the sand. This hole should be 18 inches deep, and is made with a long spade or shovel which is forced into the sand and then pressed forward, making an opening into which the beach-grass roots are thrust; the spade is then withdrawn and the sand pressed close about the roots. The grass is not planted in rows, but in quincunx, or irregular order, 1 and 2½ feet apart, according to the slope.[a] In California the planting should be done in the early fall, as the growth of roots is greater at that season, and the chances of success are consequently increased. Moreover this gives the plants the full benefit of warm soil, and of the whole season's rainfall. If sown in the spring, there is danger of the young plants drying out or burning up during the summer months. On the California coast the sowing of seed usually proves unsatisfactory, as the seed is either buried too deeply by the drifting of the sand, or blown away by the strong trade winds.

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[a] Scribner, F. L. Economic Grasses: U. S. Dept. Agric., Div. Agros., Bul. 14. 1898: Scribner, F. L. Sand-binding Grasses; reprint from Yearbook Depart. Agric. 1898.

The main objection to beach grass is the cost of planting. In Belgium, Scotland, and England, and on the coast of Massachusetts, however, the importance of reclamation has been considered to far outweigh the initial cost of planting, and hundreds of acres have been systematically planted according to the method described above. At Cape Cod, on the Massachusetts coast, some 90 acres were planted in three years, from 1895 to 1898. The cost amounted from $60 to $65 per acre, requiring 15 men and 1 horse about two days, working nine hours per day, to cover an acre with plants. On the California coast, where land is still cheap and labor costly, the farmers claim that they can not afford to pay so much for the reclamation of sand dunes.

On some portions of the English coast the work of sand-dune planting is performed by the municipal or other local governments. Heavy penalties are inflicted for pulling up or otherwise removing a single plant. This appears to be the most just method of treating what is more than a private nuisance. It does not seem fair that a farmer or private landowner should be compelled, in order to save his land, to pay for the planting of many acres of sand dunes which do not belong to him and from the use of which he can derive little or no profit. It seems more just that the duty of reclamation should devolve upon the public.

Sea lyme grass or Rancheria grass (*Elymus arenarius*), which is sparingly found in sandy places along the California coast from Santa Cruz northward, is a sand binder of only medium quality and is recommended for cultivation in company with beach grass. Professor Scribner states that "these two grasses when combined seem admirably adapted for the purpose of forming a barrier to the encroachment of the sea. The sand that the beach grass arrests and collects about itself the lyme grass secures and holds fast." It has little, if any, forage value.

Utilization of sand dunes.—The question is often asked how sand dunes may be utilized and what forage plants will grow upon them. Beach grass and sea lyme grass, though sometimes grazed when very young, can not be considered as forage plants. It has been stated that awnless brome grass (*Bromus inermis*), broncho grass (*B. maximus gussoni*), and *Bromus sterilis* will grow well in such situations; but their culture as sand binders is only in the experimental stage, and their nutritive value appears to be comparatively low. Bull clover (*Trifolium wormskjoldii*), one of the best of the native California clovers, makes a dense turf and luxuriant growth (sometimes knee-deep) in low, moist flats between the dunes, but does not appear to grow on the dunes themselves. *Atriplex halimoides*, one of the Australian saltbushes which seems well adapted to the cool summer climate of the coast, is worthy of trial in these situations. It is a valuable forage plant and seeds freely, but we have not yet demonstrated whether or not it will stand trampling. On the Santa Barbara coast sand dunes it has been found that *Eriogonum fasciculatum* and *Lotus glaber*, two native perennial plants, grow luxuriantly through the dry season and produce an abundance of nourishing feed which is much relished by stock. It is doubtful, however, whether they would tolerate the climate of the northwest coast.

Hairy vetch (*Vicia villosa*) is recommended for experimental culture as a sand binder, on account of its rapid and luxuriant growth and ready propagation by seed, but we are not aware that its value for this purpose has been determined. It is an excellent forage plant, and is becoming naturalized in some parts of the State.

Modiola (*Modiola decumbens*) has been found useful on the alkali soils of the interior, and is said to be greedily eaten by stock. If it will tolerate the cooler summer climate of the seashore, and the loose, light soil of the sand dunes, it will make a valuable addition to the list of sand-binding plants, as it roots freely from the joints and spreads rapidly, forming a dense mat of herbage.[a]

New Zealand spinach (*Tetragonia expansa*) is a succulent beach plant, said to be eaten by stock. It has already become naturalized on the sandy seabeaches along the coast in the vicinity of San Francisco.

Tree mallow (*Lavatera assurgentiflora*), native of Anacapa Island, has been successfully used in San Francisco for the last fifty years as a sand binder, wind break, and ornamental shrub. It grows to a height of 6 to 12 feet, and thrives on light, sandy soil; it is also valuable as a forage plant, cattle browsing greedily on the foliage.

It does not appear that sand-binding qualities and forage value are usually combined in the same plant, but it is possible that when once reclaimed some forage crop might be raised on the dunes. It is an open question, however, whether stock feeding on sand dunes should ever be practiced on account of the danger of starting fresh drifts. Mr. Sheppard, who has farmed at the mouth of the Garcia River for nearly forty-five years, traces all his trouble with drift sand to the time, some twenty-five or thirty years ago, when a neighbor of his commenced sheep raising on the dunes, tempted to do so by the high price of mutton and wool. In his eagerness to make money while the prices were up, this man overstocked and left the sand almost bare, with the result that it began to drift for the first time within Mr. Sheppard's memory. Profiting from this experience the latter gentleman has kept his stock off the dunes for some time, with the result that a new growth of sand grass, sand verbena, blue lupine, rush, willow, etc., is starting. But none of these plants checks the sands in the "drifts," and more vigorous measures of reclamation must be adopted if his alluvial bottom lands are to be saved.

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[a] Since the above was written this plant has been found growing wild at Tomales Bay, along the coast.

Beach grass makes an excellent and very durable thatch, and has been used for the manufacture of coarse paper.

Esparto (*Stipa tenacissima*) and albardin (*Lygeum spartum*) are worth trial on these dunes, as they have proved well adapted to the climate at Berkeley. They are natives of the sandy shores of southwestern Europe and northern Africa, and are tall perennial grasses, with long, stiff, and very tough leaves, from which ropes, baskets, mats, hats, and other articles are woven. The leaves are employed largely in England and in this country in the manufacture of paper, for which purpose they are superior to straw. Esparto is one of the most important articles of export from Algeria, and more than 2,000 tons are annually shipped from northern Africa and Spain to Great Britain. "Ten tons of dry esparto, worth from $18 to $25 per ton, can be obtained from an acre under favorable circumstances." These grasses may be cultivated either by seeds or by division of the root; but the latter is the more common method. Specimens for trial are offered by the director of the agricultural experiment station at Berkeley. (See Pl. VIII, fig. 1.)

At Cape Cod it has been found possible to raise fine growths of pine trees and shrubs on the dunes within three years after the first planting with beach grass. The species used were a native pine (*Pinus rigida*), Scotch pine (*P. sylvestris*), seaside pine (*P. maritima*), and Austrian pine (*P. austriaca*), Scotch broom (*Genista scoparia*), and bayberry (*Myrica cerifera*). (Pl. VIII, fig. 2.) All of these would probably thrive equally well on the coast of northwestern California, but it is not necessary to import trees for the purpose, as the native coast pines, so common in the region, would answer as well or better and make fuel of an excellent quality. Of these the most valuable for this purpose would be the Monterey pine (*Pinus radiata*) and the prickle-cone pine (*P. muricata*). The scrub pine (*P. contorta*) is also valuable, particularly as a wind-break. Some of the rapidly growing Australian acacias, particularly *A. longifolia sophoræ* and *Albizzia lopantha*, are also satisfactory as nurse trees, wind-breaks, and for ornamental effect. Such trees and shrubs can easily be raised when once the beach grass is established by scattering seeds among the tufts of the latter. In addition to their value for fuel, such a growth of trees acts as a wind-break, an exceedingly useful feature in such localities.

THE REDWOOD BELT.

As before noted, the redwood belt consists for the most part of a dense forest of timber occupying a narrow strip of country immediately back of and almost parallel with the coast. Owing to the immense

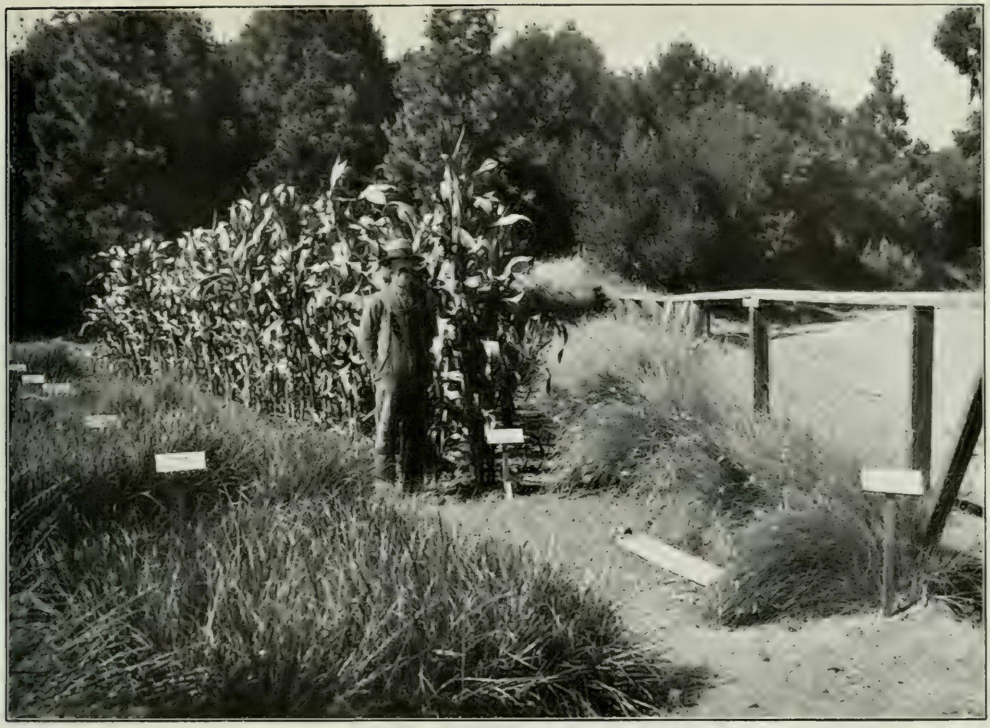

FIG. 1.—VIEW IN GRASS GARDEN, AGRICULTURAL EXPERIMENT STATION, BERKELEY. ALBARDIN AT THE RIGHT.

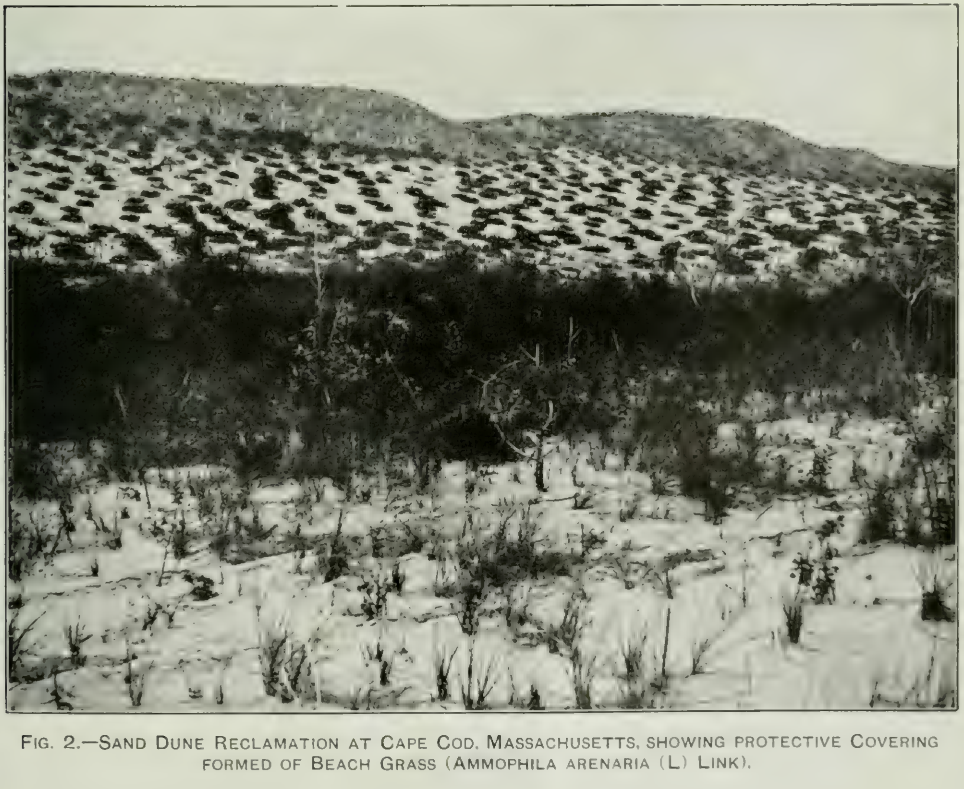

FIG. 2.—SAND DUNE RECLAMATION AT CAPE COD, MASSACHUSETTS, SHOWING PROTECTIVE COVERING FORMED OF BEACH GRASS (AMMOPHILA ARENARIA (L) LINK).

size of the trees and their abundance, the forest shade is here very dense. On the bottom lands few other species of trees are met with. On the ridges forming watersheds between the different forks of the coast rivers the redwoods are more scattered, and other species of trees, together with some brush, occur more frequently.

Grasses are scarce in the redwood forest, *Bromus lævipes*, *Melica bromoides*, *Savasbana macrophylla*, *Trisetum canescens*, and *Deschampsia elongata* being the prevalent species. These grow mainly near the borders and openings of the forest, and provide only scant feed for stock. The rare but characteristic *Asperella californica*, found in the redwood belt near San Francisco, does not appear to occur as far north as Mendocino County.

Forage plants other than grasses are not plentiful, and are principally eaten by hogs and other stock as a change of diet from excessively luxuriant range feed. Of these the following are noteworthy: Squaw lettuce (*Claytonia perfoliata*) is said to be a favorite food of cattle and hogs. Thistles (*Carduus* spp.) and the tubers of wild horseradish (*Dentaria* sp.) and roots of bracken (*Pteris aquilina lanuginosa*) are eaten by hogs. *Oxalis oregana* is sometimes eaten in small quantity by cattle and horses. The common sword fern (*Aspidium munitum*) is said to be eaten readily by calves and stock for a day or two after feeding on clover on the ranges. Hogs doubtless also feed on salal-berries (*Gaultheria shallon*) and huckleberries (*Vaccinium ovatum*), which are abundant in the redwood forest, and on the bulbs of liliaceous plants. Acorns of *Quercus densiflora*, chinquapin nuts, manzanita berries, and some deer brush are found on the higher ridges.

The introduction of tall oat grass, rescue grass, awnless brome grass, and wood meadow grass (*Poa nemoralis*) on the higher dry ridges might increase the amount of forage. It is not likely that any valuable forage plants will be found to thrive in the forest itself; nor would it be desirable from the point of view of the lumberman and forester to attempt to turn the forest proper into pasture land, the two interests being diametrically opposed.

When cleared, this redwood land, where not too steep, makes good pasture if sown to orchard grass and white clover. On account of the astonishing vitality of the redwood stumps, however, it is found necessary to go over the ground at least once a year chopping off suckers in order to keep the land clear. It is said that if this is done at the end of July or early in August it is only necessary to do it once a year, but that if cut at any other season the operation has to be repeated one or more times during the year.

The narrow strips of bottom land, where cleared of timber, produce excellent forage and general farm crops.

FODDER CROPS.

FODDER CROPS NOW CULTIVATED.

The principal fodder crops cultivated in the region are noted here. Oats is the most extensively grown hay crop. Next in importance are red clover, wheat, barley, Italian ray grass, alfalfa, and velvet grass. Small quantities of timothy, many-flowered ray grass, orchard grass, and rye are also used. Mixed hay crops are seldom, if ever, grown. Wild hay is mown in a few mountain valleys, and the wild oats on the hillsides are sometimes made use of in the same manner.

For soiling and ensilage field peas, red clover, alfalfa, corn, oats, and barley are grown. Tares, alsike, sainfoin (esparcette), and crimson clover do not appear to be used.

For root crops carrots are most commonly grown. Mangel-wurzel is being tried in one or two places along the coast. Turnips and parsnips do not appear to have been tried. The climate is probably too dry in summer for turnips, except in the extreme north.

PLANTS RECOMMENDED FOR CULTIVATION OR TRIAL.

Beach grass (*Ammophila arenaria*) is an invaluable grass for checking the spread of drift sands. The method of planting is discussed on page 59.

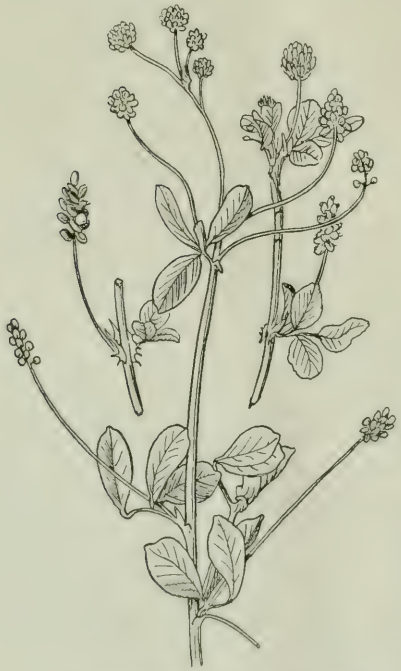

FIG. 1.—Black medic (*Medicago lupulina*).

Black medic (*Medicago lupulina*) (fig. 1) seems to be well adapted to the climatic conditions of this region, as it has become thoroughly naturalized and grows luxuriantly in several localities. It is considered a useful pasture plant for wet meadows.

Of blue grama (*Bouteloua oligostachya*) Professor Scribner writes as follows:

> It is a perennial, 6 to 18 inches high, its strong rhizomes and numerous root leaves forming dense and more or less extensive patches of excellent turf. * * * It frequents the bench lands of Montana, growing at elevations of from 3,000 to 4,000 or 5,000 feet, and not infrequently covers wide areas. No other grass better withstands the trampling of stock, and it is unsurpassed for grazing purposes. In the early days in the Southwest it formed a large proportion of the hay delivered at the various military posts and stage stations and was considered the best obtainable there. Like the buffalo grass, it cures during the dry season in the turf into perfect hay, losing none of its nutritious properties.

It has given satisfactory results at Berkeley, and is a very promising grass for dry, open upland ranges.

Buffalo grass (*Bulbilis dactyloides*) is low growing, rarely more than 5 or 6 inches high, producing numerous creeping and widely spreading branches, which root at the joints, each joint producing a new plant. In this manner it rapidly spreads over a wide area, forming a close mat of fine-leaved herbage greatly relished by all grazing animals. At Berkeley buffalo grass is a summer grower, not starting before April, but continuing green till late in the fall. It withstands drought well, and on this account would probably form a valuable addition to the summer pasture of the upland ranges, supplementing the winter feed of the prevailing annual grasses. Seed is not easily obtained, but the plant is readily produced by roots, which should be planted in early spring and protected from stock till well established. Small quantities of roots can be obtained on application to the Director of the Agricultural Experiment Station, Berkeley.

Bur clover (*Medicago denticulata*) (fig. 2) is one of the most nourishing forage plants for late summer feed. Cattle do not touch it early in the season, so that it has opportunity to mature large quantities of its prickly seed pod (burs). When ripe the seeds are said to contain a large proportion of nutritive matter and are eaten with great avidity by stock, either from the plant or licked up from the ground after falling, in July, August, and September, the season when green feed becomes most scarce. Cattle placed on stubble in which there is an abundance of bur clover become exceedingly fat at this season of the year. As the burs become badly entangled in the wool of sheep, this plant is not desirable for sheep ranges, but in its stead the closely related smooth bur clover might be grown.

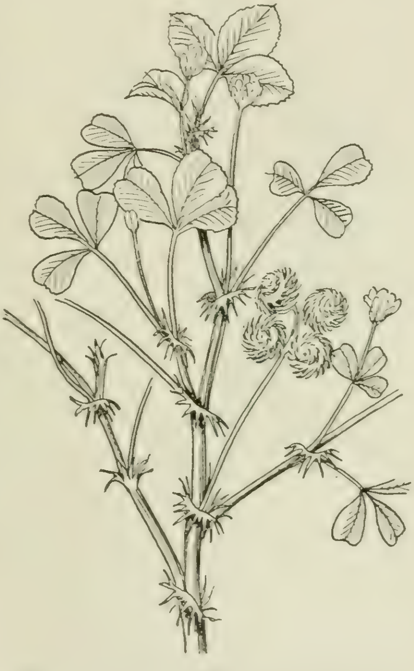

FIG. 2.—Bur clover (*Medicago denticulata*)

Bur clover is said not to thrive so well on the drier uplands back from the coast, but it is nevertheless worth trial in such situations. It luxuriates in the comparatively moist valleys. It is best sown by scattering the burs over the ranges in autumn, as they will germinate and take root with the advent of the first rains. It is not necessary to harrow the ground or to cover the burs, unless they are sown in spring. The burs are offered for sale by San Francisco seedsmen, or can readily be collected in great quantity in the counties around San Francisco Bay, where it is abundant.

California lotus or Dakota vetch (*Lotus americanus* or *Hosackia purshiana*) (fig. 3), on account of the lateness of its growing season, is considered valuable as a range forage plant, helping to fill the gap between the drying up of the ripened annual grasses and the starting of the new autumn growth. It is thoroughly at home on dry upland ranges, occasionally growing even among chaparral. Seed of the California lotus is not on the market and must be collected in its native habitat.

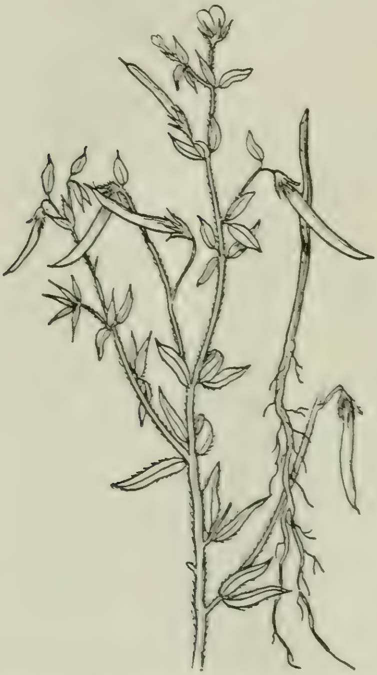

FIG. 3.—Dakota vetch (*Lotus americanus*).

Creeping bent (*Agrostis alba stolonifera*) is a valuable perennial pasture grass, making a good bottom growth. On account of its running rootstocks it is useful for mixing with less distinctly turf-forming species. It is not a productive hay grass. Creeping bent requires a moist soil, and is most likely to succeed in the mountain valleys.

Diss (*Ampelodesmos tenax*) is a tall, coarse species from the arid regions of North Africa which was introduced by the Agricultural Experiment Station at Berkeley a few years ago. Seeds of this plant were later received from Professor MacOwan, of the Agricultural Department of Cape Colony, as of "a forage plant;" shortly afterwards the writer learned through a correspondent in Lake County that he had received seed of the original distribution made by the station and that the plant had proved remarkably successful with him, producing a great deal of forage on dry, chaparral-covered hillsides where no other forage plants would grow, and that it was greedily eaten by stock.

Field peas (*Pisum arvense*) are already grown along the coast for feeding to dairy cows during the dry summer months. Still greater use can be made of this sweet, palatable, and very nutritious fodder plant with the increasing use of the silo, as it makes an excellent quality of ensilage. As a ration for stock, ensilage of oats and peas mixed is considered almost unrivaled. Some reported failures with trial crops of field peas are probably due to the use of weevil-damaged seed, and careful examination of the seed should be made before purchasing, to avoid disappointment. Peas and oats (or rye) for ensilage may be sown together, as the former will climb up and help to support the latter.

Hard fescue (*Festuca duriuscula*) is a valuable pasture grass on dry, sandy soils unfit for the growth of better grasses, as it resists long periods of summer drought. Although it is a bunch grass, not producing a turf, it can be used to advantage in mixtures with other grasses. It grows well at Berkeley.

Johnson grass (*Andropogon sorghum halepensis*) in the Southern States yields a good crop of hay, which is said to be much appreciated by stock, but in the coast region of middle and northern California it has not given great promise as a hay grass. When once established it becomes one of the most troublesome and most difficult weeds to eradicate from cultivated ground. The root-stocks are produced in great abundance, literally filling the soil; they develop very rapidly, are fleshy, and are said to be much liked by hogs. It would be well worth trial in openings among the redwoods on the headwaters of the Noyo and Navarro rivers, where large bands of hogs are raised in the woods. If seeds and pieces of root were carried down these smaller coast streams, they would not be likely to do any damage to farm lands, on account of the narrowness and depth of the gorges through which they empty into the ocean and the absence of broad alluvial flood plains. It appears unwise, however, to introduce Johnson grass along the headwaters of Eel River, on account of possible injury to the valuable farm lands at the mouth of that river; being one of the richest sections of the whole region of northwestern California, deterioration of land values there would tend to increase taxation over the rest of the region. Johnson grass has been tried with only unsatisfactory results in dry, arid soils in California.

Hairy vetch (*Vicia villosa*) is being strongly recommended as a forage crop on account of its vigorous growth and high nutritive value. Smith states that hairy vetch is an excellent soiling crop, one of the best that has been introduced into the United States, although, on account of the high price of the seed and the large amount which must be sown per acre, it has not been widely cultivated. The seed should be sown at the rate of a bushel and a half per acre. The nutritive value of the hay is high, analyses by Coudon in 1890 showing 23 per cent of crude protein. The yield varies from 1½ to 4 tons per acre, according to the fertility of the soil. Hairy vetch has proved well adapted to the climate of Berkeley. It might be sown with oats or rye for an ensilage crop, and is also recommended for trial as a sand binder, on account of its rapid growth.

Knot grass (*Paspalum distichum*). A valuable forage grass for overflowed lands, the margins of lagoons, lakes, and ponds. The yield varies considerably with the season; in wet years knot grass will yield a good crop of hay, but in dry seasons there will be scarcely enough foliage for forage. The stems are somewhat succulent, and with the leaves, are tender and much liked by stock. In the marshy borders of the lagoons at Crescent City it has formed a valuable addition to the wild forage, and around Clear Lake it is said to have taken possession of the Tule lands within the last few years.

Meadow foxtail (*Alopecurus pratensis*), Professor Scribner says, "is a valuable grass for moist meadows and pastures, particularly the latter, on account of its early growth, being one of the earliest of cultivated grasses. It is very hardy and on good soil yields a large amount of excellent forage. In Europe it is regarded as one of the best pasture grasses. It should enter into all mixtures for permanent pastures, because it is very lasting, highly nutritious, and earlier than most other species. It is never sown by itself, but is always mixed with other grasses and forage plants, because it gives a full yield only in the second or third year." It soon dies out from poor and dry lands; and though adapted for moist situations, and consequently for irrigated lands, it will not endure stagnant water.

This grass must not be confused with the "large foxtail" and "small foxtail," species of Hordeum, which are such troublesome and injurious grasses. They are not even nearly related plants and bear no resemblance to each other.

Orchard grass (*Dactylis glomerata*) yields a heavy crop of excellent hay and is a good pasture grass for woodland pastures, yielding excellent early grazing. "The aftermath is unequaled in amount by any of the grasses ordinarily cultivated for hay." Professor Scribner says orchard grass has been known to yield 27,905 pounds of green forage, 11,859 pounds of hay, and 11,910 pounds of green aftermath per acre.

The success of orchard grass for woodland pastures has already been demonstrated in the region of Scotia and Arcata. It has also been tried with success between Willits and Sherwood. The main objection raised against it is that it is difficult to obtain a good stand during the first year. This difficulty can largely be obviated by sowing the seed of some rapidly developing grass, such as tall oat grass or Italian ray grass, at the same time. These will also act as fillers or bottom grasses, occupying the spaces usually left between the tufts of orchard grass. Moreover, Professor Scribner states: "The tendency of orchard grass to form tussocks is much diminished and the sward greatly improved where sown with other grasses." He also recommends heavy rolling "for checking or preventing the tufted growth which this grass naturally assumes; by this operation the tufts are pressed down to the level of the other grasses and the turf becomes more uniform." When sown alone, 3 to 4 bushels of seed are required to the acre.

Ray grass (*Lolium* spp.). Three distinct varieties are sold by seedsmen, and much doubt and confusion exist as to their relative merits and uses and as to the differences by which they may be distinguished.

Italian ray grass (*Lolium italicum* A. Br.) (fig. 4) is a rapid-growing grass, forming a dense turf, and in Europe is valued as one of the best hay grasses for temporary pastures and as a nurse crop for red clover, orchard grass, or meadow foxtail. As it runs out in two or three years, it is not recommended as the sole ingredient of permanent pastures. Professor Scribner states that "on stiff, heavy clays, or on very dry soils, it does not do well, but on good, calcareous loam or marls, or on moist, loamy sands, when the soil is in good condition, it is very productive, and no other grass repays manuring so well. Few grasses develop more rapidly than this, and where the soil is rich and its fertility maintained by applications of liquid manure, cuttings may be obtained within three or four weeks from seeding, and at intervals of a month or six weeks successive crops may be harvested."

On the Eel River bottom lands this is considered the best variety for cultivation, as it is such a rapid grower, shooting up even at the end of July or in August. The objectionable feature is its habit of running out after two or three years. This difficulty can be remedied only by resowing.

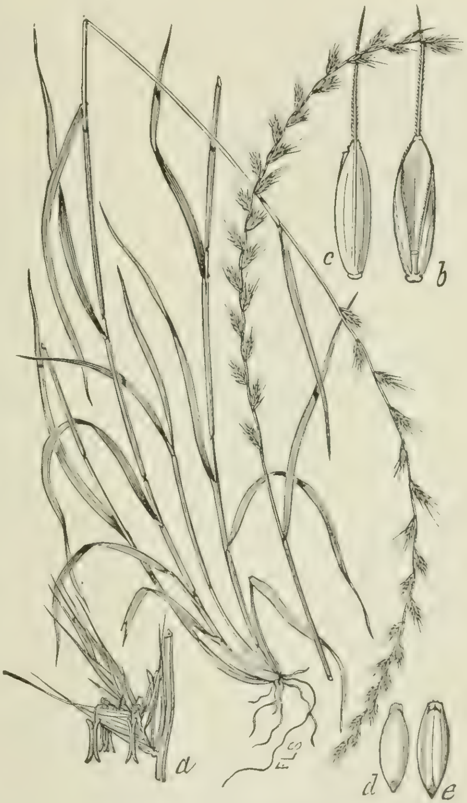

FIG. 4.—Italian ray grass.

Italian ray grass may always be distinguished from other varieties by its few-flowered spikelets and long awns (beards) (fig. 4). The young foliage is of a bright green color.

English perennial ray grass (*Lolium perenne*) is much more permanent in character than Italian ray grass, but is less rapid in growth and starts later in the season. In England it is considered a very valuable forage plant, being particularly well adapted to the climatic conditions, but Professor Scribner considers that in this country it will never be as highly esteemed as timothy. Perennial ray grass is best suited to moist, rich loams or clays, and responds promptly to the application of quick manures. Like Italian ray grass, the perennial species has but few flowers to the spikelet, but it is usually at once distinguished by the absence of awns. The young foliage is of a dark green color.

Australian ray grass (*Lolium perenne tenue*) is nothing more than a perennial ray grass which appears to have developed greater drought-resisting qualities by long cultivation in Australia. It is a somewhat wiry, tough form, especially adapted to cultivation on dry hillsides.

Many-flowered ray grass (*Lolium multiflorum*) is a variety having very large spikes and many-flowered spikelets. It has become abundantly naturalized in northern and middle California, and seems well adapted to the climate. It has recently become naturalized on the hills near Cloverdale, and is there considered a valuable forage grass. On the bottom lands of the Garcia and Eel rivers it grows luxuriantly, and in the former locality is used as a hay crop, yielding fully 3 tons to the acre. (Sheppard.)

Red clover (*Trifolium pratense*) is one of the heaviest producers of foliage, and the most nutritious of any of our cultivated forage plants. The climate over a large proportion of the State of California is not adapted to its culture, but there is no apparent reason why it should not thrive admirably in the higher mountain valleys of northwestern California. It is possible that the soil of Sherwood Valley may prove too sandy for this species, but its importance as a forage crop makes it well worth a thorough trial there. In heavy alluvial soil at the experiment station at Berkeley and on the Eel River bottom lands it has produced immense crops. It is frequently found, however, that red clover runs out after a few years. Professor Hilgard considers this is undoubtedly due to excessive acidity of the soil, which can be counteracted by treatment with lime (see p. 55). In England it is customary to sow Italian ray grass and red clover together, the former acting as a nurse crop for the latter, keeping out weeds and increasing the first year's yield, then dying out.

Red fescue (*Festuca rubra*) is a good bottom grass, having running rootstocks, which form a compact and durable turf, and producing a large quantity of fine root leaves. Red fescue endures varied conditions of soil and exposure, and is recommended both for woodland pastures and open meadows and for either sandy or clay soils. It should be tried in the mountain valleys, both on sandy alluvial or gravelly soils, and should also be used for the renewal of the open range, as its habit of growth will tend to check the washing of the soil and it withstands trampling by stock.

Redtop (*Agrostis alba*) is considered in the East as one of the best grasses for permanent pastures and meadows, making a "very resistant and leafy turf, which well withstands the trampling of stock." It needs a moist soil, and may prove useful in the higher valleys.

Reed fescue (*Festuca arundinacea*) is a tall, vigorous, and hardy grass, yielding a large amount of hay, which is said to be of excellent quality. It has made a splendid showing at the experiment station at Berkeley, where it is now being propagated for distribution. The climate and soil seem to suit it well. It thrives best on comparatively moist soils and is well worth trial in mountain valleys and bottom lands as a mixture with other grasses.

Sheep fescue (*Festuca ovina*) is a valuable bunch grass for pastures on dry, sandy soils, especially if used in mixtures. Seed of the native varieties growing on the open ranges could be collected with little expense and used in the preparation of permanent pastures.

Awnless brome grass (*Bromus inermis*), though a native of Europe, was introduced into California from New Zealand about the year 1880 by the Agricultural Experiment Station of the University of California. It is a perennial with stout, creeping rootstocks and stems 2 to 5 feet high, and is useful both for pasture and meadow. It is a good winter grower. Its nutritive value is comparatively low, but it is well worth trial on the poorer sandy soils along the coast, as it is one of the most promising grasses for such situations. It is unusually resistant of drought, and when once established is somewhat difficult to eradicate. If sown alone, about 3 bushels per acre is recommended.

Tall oat grass (*Arrhenatherum elatius*), a perennial, has been found well adapted to the climatic and soil conditions at Berkeley. It makes an earlier start than almost any other winter grass grown, and produces a heavy stand of hay. Professor Scribner reports that on rich, clayey loam it has been known to yield 17,015 pounds of green fodder, 6,380 pounds of hay, and 13,612 pounds of green aftermath per acre. It grows rapidly, blossoms early, and when cut dries out readily. On good soils three or four cuttings may be obtained during the season. The early winter growth is much relished by stock, but it is said that later in the season it becomes somewhat bitter and cattle do not care for it except in the form of hay. It is therefore best adapted for permanent winter pastures which are to be laid off as summer meadows. Tall oat grass is not suited to heavy, moist soils, but thrives best on loamy sands or loams. It is said to grow on soils too poor to produce other crops, and therefore seems particularly well adapted to cultivation on the sandy bluff soils of the coast and the white-ash prairies as a substitute for mesquite (*Holcus lanatus*), to which it is far superior, both in quality and yield. It should also be tried, along with other grasses, in the mountain valleys at the headwaters of the Eel and Russian rivers. It is doubtful whether it would do well or prove as serviceable as other crops on the bottom lands of the Eel River and of Humboldt Bay.

As it does not form a very compact turf, tall oat grass should be sown in company with other grasses, particularly those which form a good leafy bottom and have running rootstocks, such as white bent. As it makes a good stand the first year, it might be sown with orchard grass. The one species would largely remedy the defects of the other. In the East and in Europe tall oat grass is sown in the spring, but in the Southern States and in most parts of California September will be the best time for sowing. Professor Scribner recommends that if sown alone, 5 or 6 bushels of seed to the acre should be used, which at the present price of seed (about $3.25 per bushel, or $18 per 100 pounds) will be considered almost too heavy an outlay for the farmer. It seeds abundantly, however, and by purchasing a small quantity of seed one season enough can be harvested to sow a large area the following year. In this way, too, its merits and adaptability to local conditions can be better determined. "Owing to the structure of the seed, it may be sown deeper than most other grasses."

Timothy (*Phleum pratense*) is grown to a limited extent in Sherwood and Long valleys, but is said to "run out" within a few years. This is probably due to sowing alone and to pasturing too late in the rainy season, either of which methods of treatment renders the grass more liable to be trampled out. If used as a soiling or silage crop, this difficulty would probably not be met with. In the East and in Europe it is customary to sow timothy in mixtures with other grasses and clovers. It is considered satisfactory only on somewhat moist, loamy, or clayey soils and is apt to give a light yield on dry soils. It is not likely to succeed in northwestern California, therefore, except on bottom lands and in mountain valleys. Professor Scribner recommends sowing half a bushel of seed to the acre if sown alone, or about 10 pounds if the red or alsike clovers are grown with it.

Vetch (*Vicia sativa*), an annual climbing plant, grown in Europe for several centuries as a forage plant, is considered one of the best soiling crops for cool, moist climates. Except in the New England States and Canada, it has not been considered satisfactory on this continent, on account of its extreme susceptibility to dry, hot weather. On the coast of northern California, however, there seems to be no reason why it should not be grown for silage or for green fodder for milch cows, as it makes a luxuriant growth at Berkeley and at Scotia, keeping green till the middle of May in the former locality and till the middle of June in the latter. This plant makes good summer feed for horses, but should not be fed until in full bloom, on account of its diuretic action (Smith). It is said to materially increase the flow of milk in cows. Two bushels of seed are required to the acre.

White clover (*Trifolium repens*) is a perennial, forming an excellent turf. "The foliage, though produced in small quantity, is sweet, nutritious, and eagerly sought for by all kinds of stock" (Smith). In some places white clover is reported as being disliked by stock, but this is probably due to alsike clover having been mistaken for it, as the two are much alike in general appearance. Alsike clover is somewhat bitter and is not so well liked by stock. White clover is said to possess higher nutritive value than any other species. Some of the newer selected strains, such as giant perennial white clover, have proved far superior to the ordinary wild form, yielding a much heavier crop of foliage suitable for hay. White clover grows well on the bottom lands of northwestern California around Scotia, Ferndale, Crescent City, etc., and thrives on a great variety of soils and under varied conditions. It should prove a useful forage plant on valley soils and is worth trial even on the open range. It is usually sown with other forage plants, such as Italian ray grass. If sown alone, from 6 to 8 pounds of seed to the acre is recommended.

POISONOUS PLANTS.

Mr. Sheppard, of Point Arena, reports that when he first settled there some forty-five years ago many young animals died, supposedly from eating "poison hemlock" (?), but that there are no longer any poisonous plants on his ranch, which is situated on the bottom lands of the Garcia River.

On Bear River Ridge Mr. Farley, who has handled cattle there for thirteen years, reports the presence of two poisonous plants, which, however, cause but little trouble. One he calls "larkspur;" the other is described as a plant "growing up like tobacco, about 2 feet high, and having a blue flower like larkspur." Calves are sometimes poisoned with the latter in the spring, while the grass is only a few inches high and stock are too "greedy" to carefully select their food. When the grass is 6 or 8 inches high cases of poisoning do not occur. The operation of "bleeding" is generally resorted to in cases of poisoning by these plants.

Bloating is reported as somewhat common on the ranges in spring, and bear clover (*Trifolium furcatum virescens*) is sometimes called "bloat clover," as it is considered the most common cause of the trouble. Usually bloating readily yields to the knife if the case is treated immediately.

Comparatively few specimens of poisonous plants were noted in the region, and we heard scarcely any complaint about cattle poisoning. The following species were observed:

Poison hemlock (*Conium maculatum*). A large patch was found among brush by the roadside, about 3 miles north of Miller.

Larkspur; cow poison (*Delphinium trolliifolium*) is reported "common on ridges throughout Humboldt County, where the stockmen call it cow poison" (Rattan). Apparently not common in the region, as we found it at only one place, viz, on a bank by the roadside at Acorn Station, near Korbel. It is also reported as occurring sparingly on Bear River Ridge, but a search failed to bring it to light. "Its toxic character has been questioned. Perhaps it is not equally poisonous throughout all stages of its growth" (Chesnut).[a]

Foxglove (*Digitalis purpurea*) appears as escaped from a cottage garden in the hills back of Point Arena; abundantly naturalized on the Eel River bottom lands and elsewhere along the coast. In Europe horses are occasionally poisoned by nipping the plants from gardens or by eating hay contaminated with it.

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[a] Chesnut, V. K.; Preliminary Catalogue of Plants Poisonous to Stock: reprint from Annual Report U. S. Dept. of Agric., Bureau Animal Industry, 1898.

Darnel (*Lolium temulentum*) is met with at Ukiah, Fort Bragg, Ferndale, and in Hupa Valley, but nowhere in great abundance.

False hellebore (*Veratrum californicum*) is common in moist places in Sherwood Valley and northward. Reported as poisonous to stock and said to be increasing in quantity. "The root and young shoots have been reported as being fatal to horses" (Chesnut).

Western Labrador tea (*Ledum glandulosum*) is reported by Miss Parsons[a] to be much dreaded by sheepmen, who claim that it poisons their flocks. Fortunately for stockmen, this plant is practically restricted in this region of the State to the white-ash prairies and sphagnum swamps, and is rarely met with in open pastures. The only places noted by the writer where stock would be likely to find access to it were some swamps on the cattle ranges of the Point Arena bluffs. It also occurs in similar spots on Point Reyes.

Buckeye (*Aesculus californica*). The fruit is generally regarded as poisonous to stock, but may easily be converted into food by washing and boiling. It is asserted that a small quantity will cause cows to slip their young (Chesnut).

Rhododendron (*Rhododendron californicum*) is reported from Oregon as poisonous to sheep (Chesnut); abundant on the White Plains.

Azalea (*Rhododendron occidentale*) is very much dreaded by sheepmen who drive their flocks into the southern Sierras for pasture. Investigation has shown that the leaves contain a poisonous substance (Chesnut); common along streams throughout northwestern California.

Calico-bush (*Kalmia glauca microphylla*), common on Trinity Summit, may possibly prove poisonous to sheep, as some of the eastern species of the genus are considered among the most dangerous of cattle poisons.

Milkweed (*Asclepias eriocarpa*). Several authentic accounts of the poisoning of sheep have been secured against this plant in Mendocino County. It is especially feared on very warm days by sheepmen when they are compelled to drive their flocks through dry, barren valleys. It sometimes grows on cultivated land, and is cut with hay (Chesnut).

Cocklebur (*Xanthium canadense*) appears in this region, as already noted. The young seedlings are reported from Texas as being rapidly fatal to hogs (Chesnut).

FUNGOUS PARASITES.[b]

The injury to the forage plants of the region under consideration, caused by parasitic fungi, is exceedingly slight, in so far as can be estimated from a rapid survey during a single season. The elevated upland ranges are singularly free from pests of this sort, but in the moister bottom lands many of the common grass-inhabiting species of rusts and smuts are found.

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[a] Parsons, M. E., "Wild flowers of California, their names, haunts and habits." San Francisco, 1897.

[b] The notes here presented were prepared by Dr. W. C. Blasdale.

Ustilago avenæ (Pers.) Jensen, oat smut, is seldom absent from fields of cultivated oats, and in certain seasons is said to cause considerable injury. It is occasionally found on the wild oats.

Ustilago holwayi, Dietel., is frequently found on *Hordeum nodosum*, but can scarcely be considered a pest.

Ustilago bromivora, Fisch., is found on *Bromus hordeaceus glabrescens*, but is not widely distributed.

Puccinia rubigo-vera (D. C.) Wint., orange leaf rust, is not uncommon on *Bromus secalinus* and *B. carinatus*, but the amount of injury effected by it is not great.

A yellow-spored Uredo is almost constantly associated with *Holcus lanatus*, and, were this grass a more valuable one, the rust might be considered a serious pest. Observations on this species in other portions of the State have shown that it persists throughout the year without the formation of other spore forms, which renders its identification impossible.

Uromyces minor, Schroet., clover rust, frequently injures certain species of Trifolium, especially *T. dubium* and *T. microdon*. In other portions of the State it is especially injurious to *T. gracilentum*.

What is probably the uredo stage of *Uromyces striatus*, Schroet., was also found in abundance in a single locality on *Medicago lupulina*.

Pseudopeziza trifolii, Fckl., is widely distributed and injures nearly all the species of Trifolium, but especially *T. cyathiferum* and *T. microdon*.

The species enumerated below are of frequent occurrence, though of no special economic significance: *Æcidium sommerfeltii* Johanson, on *Aquilegia truncata; Æcidium hydrophylli* Peck, on *Hydrophyllum capitatum; Æcidium pseudo-balsameum* D. and H., on *Abies grandis; Actinonema rosae* (*Lib.*) Fr., on *Rosa gymnocarpa; Doassansia alismatis* (Nees) Cornu, on *Alisma plantago; Puccinia circææ* Pers., on *Circæa pacifica; Puccinia densa* D. and H., on *Viola glabella; Puccinia bistortæ* (Strauss) Wint., on *Polygonum bistortoides; Puccinia asari* Link, on *Asarum caudatum; Puccinia gentianæ* (Strauss) Link, on *Gentiana menziesii; Puccinia malvacearum* Mont., on *Althæa rosea* and *Malva* sp.; *Puccinia menthæ* Pers., on *Micromeria douglasii* and *Monardella undulata; Puccinia mesnieriana* Thuem., on *Rhamnus crocea; Puccinia nodosa* Ell. & Hark., on *Brodiæa capitata; Puccinia melanconioides* Ell. & Hark., on *Dodecatheon cruciatum; Puccinia mirabilissima* Peck, on *Berberis nervosa; Puccinia hieracii* (Schum.) Mart., on *Carduus lanceolatus; Puccinia plumbaria* Peck, on *Phlox gracilis; Puccinia symphoricarpi* Hark., on *Symphoricarpus mollis; Puccinia pimpinellæ* (Strauss)

Link, on *Osmorrhiza brevistylis; Puccinia wyethiæ* Peck., on *Wyethia angustifolia; Phragmidium subcorticium* (Schrank.) Wint., on *Rosa gymnocarpa; Phragmidium rubi-idæi* (DC.) Karst., on *Rubus parviflorus; Sphærotheca humuli* (DC.) Burrill, on *Collomia heterophylla; Synchytrium pluriannulatum* Farlow, on *Sanicula menziesii; Triphragmium echinatum* Lev., on *Selinum pacificum; Uromyces aterrimus* D. & H., on *Allium unifolium; Uromyces hyperici* (Schw.) Curt., on *Hypericum anagalloides; Uredo arbuti* D. & H., on *Rhododendron californicum.*

PHYTOGRAPHIC NOTES.

The southern portion of the region under investigation is included by Dr. C. Hart Merriam in his Transition Zone. The Canadian Zone covers a large part of Del Norte and northern Humboldt counties and the Hudsonian Zone occupies the highest mountain summits. Our general collections have not yet been completely worked up, so that we can not give adequate lists of the plants by which each of these zones is characterized.

In general features the flora over the largest portion of this region differs little from that of the region immediately north of San Francisco Bay. Some species of the latter area do not extend as far north as the region under investigation, but in their stead occur species characteristic of a more northerly climate. *Sequoia sempervirens* is the most characteristic tree, here reaching its greatest development and occurring throughout the area. Immediately along the coast occur other coniferous trees. In Mendocino County *Pinus muricata* and *P. contorta* are the prevalent species, and a few specimens of *Abies grandis* occur. The pines were not observed along the coast of Humboldt and Del Norte counties being replaced by *Abies grandis*, *Picea sitchensis*, and *Tsuga mertensiana.*

The highest summits of the South Fork Mountains, which separate Humboldt County from Trinity County, are characterized by a highly interesting flora, showing a close connection with that of the Northern Sierra Nevada, with which it is topographically connected by the Salmon and Scott ranges and Mount Shasta. Our collections from this portion of the region have not yet been completely worked over, but they contain such interesting Sierran species as *Arctostaphylos nevadensis*, *Caltha biflora*, *Dicentra uniflora*, *Kalmia glauca microphylla*, *Quercus chrysolepis vacciniifolia*, *Pentstemon newberryi*, *Ribes cereum*, *Sarcodes sanguinea*, *Spraguea umbellata*, *Vaccinium arbuscula*, and *Viola blanda.*

But little systematic work has been done on the flora of this region. Collections have been made by H. N. Bolander, C. G. Pringle, Volney Rattan, C. C. Marshall, V. K. Chesnut, Elmer R. Drew, W. C. Blasdale, M. A. Howe, J. P. Tracy, H. P. Chandler, Miss Alice Eastwood, and the writer. Bolander's and some of Rattan's notes are recorded in the Botany of the State Geological Survey, and several of Marshall's novelties have been described in the writings of Prof. E. L. Greene. The only publications dealing directly with the flora of the region are those of Blasdale and Drew.

SUMMARY.

1. The principal industries of the region under consideration are stock raising, dairying, lumbering, and barking.

2. Lumber and tanbark are practically confined to the redwood belt, a narrow strip of country running nearly parallel with the coast line.

3. Dairying is practically restricted to a few points along the coast, at Point Arena, and particularly the fertile flood plains near Eureka and Crescent City. The mountain valleys at the headwaters of the various branches of Eel River seem to be well adapted to dairying where they are within accessible distance of a market or shipping point.

4. The best grazing areas are (a) the coast bluffs, particularly near Point Arena and in the Cape Mendocino country; (b) the mountain valleys above referred to, and (c) the upland ridges of the plateau. The plateau ridges furnish by far the largest grazing area. This plateau country is not adapted to general agriculture.

5. Annual (seed growing) grasses seem to be better adapted to the upland ranges than perennial ("root growing") species. They reproduce themselves from seed much more readily after trampling out than the perennial species and furnish a large amount of early winter feed.

6. Naturalized forage plants, introduced accidentally from foreign countries, such as alfilerilla, bur clover, rat-tail fescue, barley grass, and soft chess are proving better able to stand trampling and grazing than the native species.

7. The maximum carrying capacity of the ranges has been reduced from 5 acres per head of cattle to 10, 12, and, it is said, even 20 acres, within comparatively few years, through excessively high land valuations and consequent overstocking of the ranges. The result of our investigations shows, and it has since been confirmed by practical stockmen who have grazed some of these ranges for years, that not less than 8 acres of range (including the usual proportion of brush and timber) should be allowed to each head of cattle. At this ratio the range can be maintained, and even improved, with judicious handling. This ratio should be made the basis of valuation in the purchase of a range, the relative amount of open range and of woodland also being taken into account.

8. The principal secret of successful stock raising in this region is to allow abundance of grass to go to seed. Seeding grass knee-deep is not wasted, as is usually supposed, but insures an abundance of

feed for the following year, not only on account of the seed scattered, but because it provides a good seed bed.

9. Sheep are no more injurious to a range, when properly handled, than are cattle.

10. On account of the importance of the tan oak to Californian industries, an investigation of the resources of the State in this direction is desirable.

11. The protection of drinking holes preserves the water supply and adds greatly to the value of the range; wherever possible proper drinking troughs should be placed at a short distance from the spring and the spring itself should be fenced. Small springs are often ruined by trampling.

12. The maintenance of springs and streams by preserving the timber and brush in their immediate vicinity is of the greatest importance to the range; it not only conserves the water supply, but also affords shelter to the stock in cold, wet weather.

13. The importance of maintaining good fences around a range should not be overlooked, and wherever practicable it is found profitable to fence off a range into several pastures, giving each one a rest from time to time.

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[Common names are in roman; botanical names in *italics*.]

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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN No. 13
B. T. GALLOWAY, Chief of Bureau.

EXPERIMENTS

IN

RANGE IMPROVEMENT

IN

CENTRAL TEXAS.

BY

H. L. BENTLEY, Special Agent,
GRASS AND FORAGE PLANT INVESTIGATIONS.

1862 1889

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office ot the Chief,
Washington, D. C., November 23, 1901.

Sir: I have the honor to transmit herewith a paper on Experiments in Range Improvement in Central Texas, and respectfully recommend that it be published as Bulletin No. 13 of the Bureau series. The paper was prepared by Mr. H. L. Bentley, special agent, Grass and Forage Plant Investigations, and was submitted by the Agrostologist.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Central Texas is a semiarid region, and is naturally one of the best grazing or live-stock sections in the Southwest. The native grasses which, prior to 1875, were most abundant in variety and quantity have been to a great extent destroyed, so that the carrying capacity of the ranges has been greatly diminished, but there are enough grass roots left to make the restoration of the pastures to their former condition possible at comparatively small expense. The experiments at Abilene were undertaken to demonstrate the truth of this statement, and the report of Mr. Bentley, special agent in immediate charge of the work, will be of more than ordinary interest, not only to stockmen of central Texas, but to all engaged in the cattle industry on the western ranges, as showing how the result in view was accomplished. What has here been done under Government direction may be done by individuals. In fact, the primary object of this report is to invite attention to the methods pursued and the actual results attained that all interested may take advantage of the experience acquired in the work. The results have demonstrated the practicability of reclaiming the worn-out ranges in central Texas, at least, within a reasonable time and expense. The land selected, which was a range below the average quality, was leased to the Department by Mr. C. W. Merchant for use in these experiments, and was fenced, in accordance with our directions, by the citizens of Abilene, and to this extent the work was cooperative with the people of that town. At the beginning of the experiments the carrying capacity of the pasture selected was 40 head of mixed cattle to the section, or 1 to 16 acres. When the experiments were concluded on April 1, 1901, the carrying capacity was estimated to be 100 head of mixed cattle for the 640 acres, or an increase of more than 100 per cent. The actual cost to the Department did not average more than 25 cents per acre per year, or 75 cents per acre for the three years. The rental of the 640 acres had doubled in actual value as the result of the three years' experiments, or, we will say, had risen from $5 an acre in 1898 to $10 an acre in 1901, giving a net increase of $4.25 per acre, or $2,720 for the section.

This office is under obligations to Messrs. D. W. Middleton, J. W. Parramore, and W. J. Bryan, of Abilene, Tex., who during the term acted as station inspectors and in many other ways cooperated and aided materially in this work. To Mr. P. O. Forbus, also of Abilene, who during three full years was foreman of the working force of the station and in many ways contributed to whatever success was secured, acknowledgments are also due.

F. Lamson-Scribner,
Agrostologist.

Office of the Agrostologist,
Washington, D. C., November 19, 1901.

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EXPERIMENTS IN RANGE IMPROVEMENT IN CENTRAL TEXAS.

INTRODUCTION.

It has been written that he is a benefactor of the human race who makes two blades of grass grow where but one grew before. May it not be said with as much reason that he who destroys the single blade is a menace to civilization? At all events, the suggestion opens up an interesting line of thought, and it may be well worth the effort involved to consider very briefly the present conditions of central Texas and the Southwest generally.

The capacity of this section for carrying live stock has been, during the past fifteen or twenty years, diminished from 30 to 50 per cent as the result of either bad management or a reckless desire on the part those who occupied it to "get rich in a hurry."

In Grazing Problems in the Southwest, and How to Meet Them, prepared by Jared G. Smith, under the direction of the Agrostologist, it is stated that the Secretary of Agriculture, fully appreciating these conditions, directed the Division of Agrostology early in 1897 to begin investigations of the forage problems and conditions throughout the regions of the Southwest with instructions that particular attention be given the native grasses and forage plants, their abundance and value, their preservation, and the possible methods to be employed in restoring the former carrying capacity of the ranges.

In line with these purposes, Mr. Smith visited central Texas in the spring of 1897. Finding there a condition of affairs that, in view of the large area of country included in his proposed field of work, called for a more extensive investigation than he could make in person, the writer was requested to undertake and make the investigations and submit a report upon the grasses and forage plants of central Texas. It was further suggested that the existing condition of the cattle ranges of the Southwest generally be looked into; that the causes of the radical exhaustion of the pasturage of central Texas particularly be determined, as far as practicable, and that a history of such exhaustion, with suggestions for its restoration, be submitted. This special commission having been approved by the Agrostologist, the writer entered upon the work, and as a result of his investigations submitted two reports covering the same. One, A Report upon the Grasses and Forage Plants of Central Texas, was published in 1898 as Bulletin No. 10, Division of Agrostology, United States Department of Agriculture; the other, Cattle Ranges of the Southwest, was published the same year as Farmers' Bulletin No. 72 by the same Department. The former contained brief accounts of the physical character of central Texas, the early and (then) present condition of the ranges, and descriptions and general observations upon the distribution and economic importance of a large number of the grasses and forage plants natural to the region. The latter report was a history of the exhaustion of the pasturage of central Texas particularly, with suggestions for its restoration. These two reports were applicable to a territory 200 miles long and 150 miles wide, between the ninety-eighth meridian and the western edge of the Staked Plains. As one result of these investigations and reports, it was decided to obtain control of a body of overgrazed land in central Texas in order to carry on, during three years, experiments in methods of practical range improvement. In March, 1898, Prof. C. C. Georgeson, then connected with the Division of Agrostology, was sent to Texas to select the land. He chose 640 acres near Abilene, and Prof. Jared G. Smith was commissioned to establish the work. In April the writer was appointed special agent in charge of this work, really the first ever undertaken either by the General Government or by State experiment stations.

The report here presented covers the work done under this appointment during the period between April 1, 1898, and April 1, 1901.

The central Texas country, to quote from Farmers' Bulletin No. 72, above referred to, includes all of the counties of Stonewall, Haskell, Throckmorton, Fisher, Jones, Shackelford, Nolan, Taylor, Callahan, Runnels, Coleman, Tom Green, Concho, and McCulloch, and parts of the counties of Kent, Scurry, Mitchell, Coke, San Saba, Brown, Eastland, Stephens, and Young. It embraces a territory about 100 miles wide east and west and about 200 miles long north and south.

The characteristics common to these counties are:

(1) An open country in the main, with some black-jack, post-oak, and live-oak timber on the uplands and ridges.

(2) A scattering growth of mesquite trees on the lands away from the streams, which, together with the timber on the streams, furnishes ample firewood and posts for fencing purposes.

(3) Numerous streams that furnish an abundance of "stock water," fringed along their banks with groves of pecan, elm, hackberry, wild china, cottonwood, and other trees.

(4) An altitude ranging from 1,500 to 1,900 feet above the sea level.

(5) A climate pure and bracing.

(6) An annual rainfall of about 20 to 35 inches, the average being about 30 inches, so distributed through the year that it suffices for range purposes, but periodically is not quite enough for the best results in farming.

(7) A temperature ranging from 90° to 102° down to —6° F.

(8) A rich alluvial soil in most of the valleys, while on the uplands there are loams generally containing a large admixture of calcareous marls, varying in color from a light gray through all the intermediate colors—chocolate, mulatto, red, brown—to black; all productive and susceptible of high cultivation, and especially rich in all the essentials for the production of cereals and grasses.

(9) A great variety of forage plants and rich grasses.

Stonewall, Nolan, Mitchell, McCulloch, Coke, San Saba, and Taylor counties, by their mountains, level plains, and rolling prairies, present a greater diversity of surface than the others. In Taylor County there are elevations of considerable altitude, one mountain range extending through it from southeast to northwest, the highest point being 519 feet above the surrounding plains. In Throckmorton, Stephens, Shackelford, Callahan, Runnels, Coleman, and Tom Green counties there are some broken areas. In the other ten counties named there are comparatively few hills and practically no mountains, the prevailing characteristic topography being the rolling or undulating prairies. In all of these counties where there are neither mountains nor hills the general surface is gently undulating, except in the immediate vicinity of the streams, where it is rough and sometimes cut up by canyons.

To the end that a proper understanding may be had of the weather conditions that prevailed here during the three years' work mentioned, the following monthly condensed data are given from the figures specially prepared for this report. They indicate the highest, lowest, and mean temperature, and the total and mean precipitation, in inches, during each month of the three years above mentioned:

	Temperature.			Total precipitation.
	Maximum.	Minimum.	Mean.	
1898.	°F.	°F.	°F.	*Inches.*
April	92	34	65	1.78
May	101	43	73	2.60
June	98	61	78	4.55
July	102	62	81	1.46
August	98	61	81	1.94
September	100	46	75	3.44
October	94	30	66	Trace.
November	81	24	51	.98
December	78	1	39	2.14

	Temperature.			Total precipitation.
	Maximum.	Minimum.	Mean.	
1899.	°F.	°F.	°F.	*Inches.*
January	72	8	42	0.51
February	78	−6	37	.01
March	93	23	58	.04
April	94	27	63	2.96
May	94	54	74	4.02
June	93	62	77	5.45
July	102	64	81	1.38
August	104	72	87	.10
September	97	52	76	.44
October	92	44	69	2.90
November	80	28	57	2.36
December	78	24	44	3.24
1900.				
January	76	17	47	.92
February	77	14	46	.53
March	88	31	56	1.54
April	84	33	63	5.43
May	91	51	70	4.11
June	105	63	81	.30
July	96	65	81	2.59
August	100	64	81	2.11
September	96	57	77	9.65
October	91	42	68	4.39
November	81	31	56	.24
December	70	15	48	.30
1901.				
January	81	15	49	.03
February	77	13	43	1.44
March	88	23	56	.72

In the four periods as above indicated are the thirty-six months during which the station work under consideration was carried on. The work covered three periods of twelve months each—April, 1898, to and including March, 1899; April, 1899, to and including March, 1900; April, 1900, to and including March, 1901. The averages of the temperature and precipitation for each of these three periods were:

	Temperature.			Precipitation.	
	Maximum.	Minimum.	Mean.	Total.	Monthly mean.
	°F.	°F.	°F.	*Inches.*	*Inches.*
First period	$90\frac{7}{12}$	$32\frac{1}{4}$	$62\frac{1}{6}$	19.45	1.628
Second period	$91\frac{3}{4}$	$39\frac{1}{2}$	$63\frac{1}{12}$	25.84	2.153
Third period	$89\frac{1}{6}$	$39\frac{1}{3}$	$64\frac{5}{12}$	31.31	2.608

It will be noticed that the total precipitation during the first period of twelve months was 19.45 inches, an average of 1.628 inches per month, about 10.55 inches less than normal. The next twelve months the total increased to 25.84 inches, still 4.16 inches less than normal. During the last year of the work the total was 31.31 inches, over 1.31 inches above normal. The work, therefore, was inaugurated under local conditions that were very unfavorable for good results. In the detailed report to follow it will be explained how such conditions militated against the work and prevented the best results; and yet, on the whole, the results actually secured were encouraging, and demonstrated the practicability of reclaiming the worn-out ranges within a reasonable time and at an expense that should not discourage farmers and stockmen. Up to within a few years past the average farmers and stockmen of the Southwest were little inclined to adopt any other than "the old regulation methods" of farming and handling live stock that had been in vogue "since the time when the memory of man runneth not to the contrary," as the old law books stated the idea. In other words, the "book farmer" was looked upon by the regulation or orthodox farmer as "a crank," a visionary sort of creature to be respected for his enthusiasm, but to be avoided in matters of business. He was deemed impractical by the men who prided themselves on being "practical farmers," but who were constantly putting into practice methods that for all practical purposes were "out of date" and wrong. Fortunately, the farmer who reads, studies, experiments, and adopts scientifically correct methods is no longer sneered at by those who are less advanced than he. They are still slow to accept his advice and adopt his methods, even when they must see or recognize their superiority to the old-time methods. In good time, however, they will accept his way of thinking and doing, and though their apparent lack of interest in the more advanced methods of farming is somewhat discouraging to those who are willing to aid them, nevertheless, year by year, a large per cent of them are reading, studying, and experimenting for themselves. In like manner, stockmen who, a few years ago, were satisfied to follow the "seven and six" plans of the old times, are beginning to realize the common sense in the latter methods, and are manifesting a strong inclination to adopt the up-to-date ways.

During the first year of the work under consideration a large number of farmers and stockmen of central Texas called at the grass and forage plant station "to see what they could see." Not a few of them were emphatic in their expressions of disapproval. During the last year of the work much interest was manifested in it, and though much too small a number of those who have followed and approved of the work, and now testify to the practical results secured, have concluded to adopt similar methods on their own properties, it is believed that many others will adopt them later. As one stockman said in the autumn of 1900, "Seeing is believing, and a half-blind man can see that this range is the best in this section, while before the Government took it in hand it was one of the very poorest." Another remarked: "Don't think that because every stockman in these parts hasn't taken up the methods adopted here they are blind or indifferent. Many of them have been watching and taking notes, and are quietly making experiments on their own places, and I predict that the others will do likewise."

The world is slow to adopt anything new, but once let it be demonstrated that it pays to do so, and no people are more ready to take hold than are the farmers and stockmen of the United States. Hence, it is reasonable to believe that within a few years advanced methods of handling the ranges will be adopted in central Texas and throughout the Southwest generally, and that where one blade of grass now grows in a very few years several will be made to grow. The soil of these ranges is quite as rich in food for grasses and forage plants in 1901 as it was thirty years ago. The seasons are as good, in fact better, in that the rainfall is somewhat greater and is more satisfactorily distributed. Hence the belief that after the proper methods for rejuvenating the ranges shall have been generally adopted, it will not be many years before the range capacity for sustaining live stock will be quite as great as it was in the sixties and seventies, when there was no better stock country to be found than that of central Texas.

HISTORY OF THE FIRST YEAR'S WORK.

SELECTION OF THE LAND.

In March, 1899, Prof. C. C. Georgeson, of the Division of Agrostology, was sent by the Agrostologist to select a section of range land on which it was proposed to undertake and prosecute experiments "to demonstrate the most practicable, and at the same time the most economic, way of treating the natural pastures in order to again cover them with the native grasses or with other species from similar regions in other countries." He put in several days looking over the many sections recommended to him for the purposes in view. Some of them were already fairly good ranges, but he was looking for one that had been run down until it was distinctly a very poor range. Some of them were valley lands altogether, the soils being uniformly rich and specially favorable for the growth, under favorable conditions, of grasses and forage plants, but he was looking for one that was poorer and if anything less favorable for range purposes than the average. He was acting on the idea that if a body of land already stocked with grasses, or one specially located, or specially rich in the matter of its soil, should be selected, no matter how successful might be the results of the experiments to be made, they would not be accepted as demonstrating the correctness of the methods adopted. There would be many who could say, with some reason, and would, in fact, say that "anybody could take as rich a range as that, with a good lot of grass to begin with, and make a favorable showing under fair conditions." What the Agrostologist wished to secure was results which, if satisfactory, would be accepted as being due to the putting into practice of correct theories and pushing them on correct lines. That is what Professor Georgeson had in mind when he selected an irregular body of land containing 640 acres lying about 4½ miles southwest of Abilene, in Taylor County. The following diagram of the land, with the explanation to follow, is submitted:

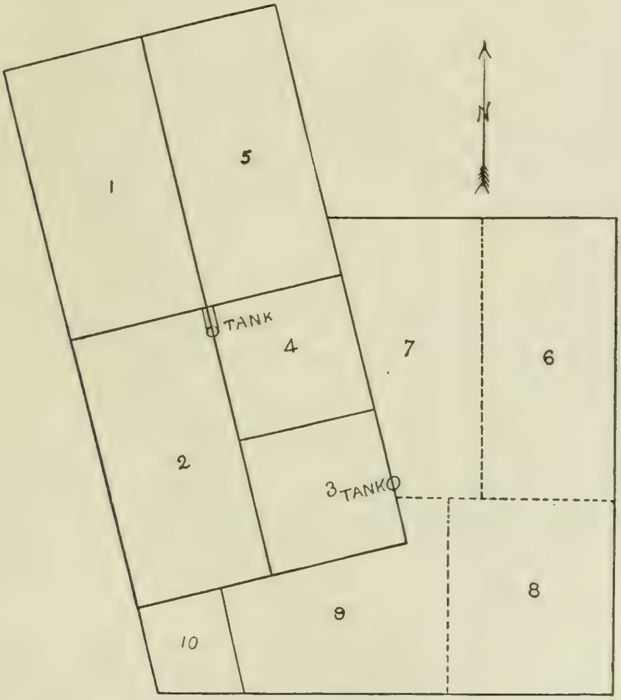


FIG. 1.—Plan of the station grounds.

Mr. C. W. Merchant, who owned the pasture which included this 640 acres, had authorized Professor Georgeson to cut out all he cared to use in any shape to suit himself. There was no running water on any part of the tract selected, but through each of the subdivisions indicated were the beds of dry branches and holes that held water after copious rains, the water flowing into Elm Creek of the Brazos River, which supplied in the main the stock water for the entire Merchant pasture. Next to these branch beds were level lands known, locally, as "second valley lands," to distinguish them from the valley lands lying next to the creeks and rivers. All of these valleys were narrow, and extending out from them were lands known, locally, as "the uplands," being level stretches, as a rule, above the valley levels, though in the north parts of subdivision Nos. 1, 5, 7, and 8 were rough hills which were considerably higher than the surrounding lands. The purpose of taking in these rough valley hills was to make it certain that a lot of very poor and unpromising land, as well as some average level uplands and some valley lands, might be included. As Professor Georgeson explained.

> If these hill lands, rough, gravelly, and rocky, very poor in quality, and now almost destitute of grass or grass roots, can be reclaimed, it will mean much more to farmers and stockmen than the reclaiming of level and comparatively rich valley lands will mean to them.

How well he succeeded in his efforts to locate the grass and forage-plant station on land below the average of the neighboring lands in favorable position, quality of soil, and quantity of grass and grass roots then in sight, the significant remarks of visitors to the station and the further facts to be hereafter stated will assist in determining.

Ex-Congressman J. V. Cockrell, of the Thirteenth Congressional district of Texas, visited the station in 1899, and remarked: "You have here about the roughest and poorest section of land in all this part of the country;" and it was quite the expected and the usual thing for visitors to the station, in 1898, to notice and comment on the fact that the land was evidently not selected with the view to securing the best. The valleys and uplands, outside of the hills, were of fair average quality as compared with the other rough lands in that part of Taylor County, but the hills mentioned were exceptionally rough and the soil very thin. It was in order to take in these hills, and also some of the richer small valleys, and a fair average of the uplands, that the 640 acres were selected in the very irregular shape indicated (fig. 1).

PLAN OF EXPERIMENTS.

Having secured the land, Professor Georgeson returned to Washington, and Prof. Jared G. Smith, then Assistant Chief of the Division of Agrostology, took charge of the work; but in a short time, his services being more essential elsewhere, he was recalled to Washington, and the writer was placed in charge as special agent, and continued in charge to the latter part of March, 1901, when, the three years' work having been completed, the station was restored to Mr. Merchant.

The section was divided by survey lines into six portions of 80 acres each, and one of 70 acres, the remaining 10 acres being set apart as a grass garden to be devoted to the cultivation of grass and forage plants. It was originally contemplated that all of the division surveys, as shown in the diagram, should be fenced, but in fact, those indicated by the dotted lines were not. The five pastures and garden fenced included 330 acres, and the four subdivisions not divided by fences, 310 acres. The work of the subsequent three years, as planned, was as follows:

Pasture No. 1 (60 acres): No treatment except to keep all stock off until June of each year, pasturing the balance of the season.

Pasture No. 2 (60 acres): To be cut with a disk harrow and stock to be kept off until June 1 of each year, pasturing the balance of the season.

Pastures Nos. 3 and 4 (40 acres each): To be grazed alternately, the stock to be changed from one pasture to the other every two weeks, thus allowing the grasses a short period for recovery after each grazing.

Pasture No. 5 (60 acres): No treatment except pasturing until June 1 and keeping stock off the balance of the season.

Pasture No. 6 (60 acres): No treatment, except to keep stock off during the first season.

Pasture No. 7: To be harrowed with an ordinary straight-toothed harrow and stock kept off during the first season.

Pasture No. 8 (60 acres): To be disked and stock kept off during the first season.

Pasture No. 9 (70 acres): Reserved for special experiments, viz, to determine—

(1) Whether or not seeds of a number of wild and cultivated varieties of grasses, and forage plants exclusive of the grasses, could be sown directly in the sod with satisfactory results.

(2) Whether the roots of certain sod and pasture grasses could be transplanted to the bare spots and a good stand secured in that way.

(3) Whether the stand of grass could be improved by opening furrows across the pastures, in which the grass seeds blown over the ground by the winds could be arrested and the stand of grass be improved.

The results of these several experiments, with the necessary details, will be stated hereafter.

CARRYING CAPACITY OF THE PASTURES.

In order to determine from year to year the extent of the improvement, if any, in the range conditions, it was necessary to ascertain the capacity of the section for sustaining stock at the very start of the work. To that end, three well-known stockmen of central Texas were invited to make a full and painstaking inspection of practically every part of the section. They were C. W. Middleton, J. W. Parramore, and W. J. Bryan, all of Taylor County and all old settlers in that part of the State, each a large owner of cattle, and, therefore, specially interested in the results to be secured. That each one of them could accurately estimate the capacity of a range to sustain stock no one in the Southwest, where they are extensively known, could for a moment doubt. It was believed, therefore, that an expression of opinion by them on the subject would be accepted as definitely determining the capacity of the particular section under consideration. They made a personal and minute inspection of every acre of the section on March 23, 1898, and unanimously reported that its utmost capacity at that time was the support of mixed stock at the rate of 1 head to every 16 acres, or 40 head to the section, in the proportion of 10 cows with calves, 15 yearlings, and 15 two-year-olds. Mr. Middleton, who during several years prior to 1898 had held his cattle in a large pasture which at that time included this particular 640-acre tract, is authority for the statement, made by him to his associate inspectors, that when he first knew it, in the seventies, its capacity for supporting cattle was quite 160 head of mixed cattle to the section of 640 acres, including the hills mentioned. He explained that the large difference between its present and its former condition was due to the fact that, in common with all the other range lands of the section, it had for years been overstocked. Prior to the date of its purchase by Mr. Merchant, only a short time before 1898, it had first been part of the open range in which everybody's cattle roamed at will, and later had been held under lease; and in each case the cattle roaming on it had been permitted to graze it closely. This was the situation, say, April 1, 1898, and the problem to be solved was: "Is it practicable, as the result of carefully planned, systematic work, to take this land, which once had four times its present capacity for sustaining stock, and restore it to its original value as a pasture?"

SEEDING THE GROUND.

Before Professor Smith left he personally superintended the experimental work as planned to be done on pasture No. 9. He had several acres sowed, without disturbing the surface, to the seeds of quite a variety of grasses and forage plants, including several of the weeds recognized by stockmen as having definite value as early stock feed. He also made an effort to get a stand of Texas blue grass and curly mesquite by transplanting fragments of sod to the bare spots, but on account of the dry weather that followed practically none of the seed sown germinated, and all of the sods put in the ground died. He also had the 10-acre garden tract broken, but necessarily, it being sod land, the breaking was shallow—only deep enough to turn under the sod. On this tract he sowed broadcast seeds of many varieties of grasses and several varieties of alfalfa, and later several varieties of cowpeas and velvet beans.

A shower following these sowings, some of the seeds germinated, but after a brief effort to exist only the alfalfa, cowpeas, and teosinte survived the distressing shortage in rainfall that followed. The precipitation during April, 1898, was much below normal, being only 1.78 inches, and the maximum temperature was 92°, much above normal. There were only 2.60 inches of rainfall during May, and the temperature for the month was abnormally great, the maximum being 101°. During June the precipitation was satisfactory, being 4.55 inches, but it came too late to save the garden work. In July the temperature went to 102°, and the rainfall fell off to 1.46 inches. During the next month the weather continued favorable, the rainfall being 1.94 inches, the temperature ranging between 81° and 98°. September promised more satisfactory weather, but while the rainfall was 3.44 inches, the heat continued excessive, reaching as high as 100°. There was but a trace of rain during October, and the mercury remained up in the nineties, and went up to 94°. In November less than 1 inch of rain fell, and during the next three months there was not enough to materially raise the average for the twelve months, the precipitation during December being 2.14 inches, only 0.51 inch during January, 1899, and only 0.01 inch during February following. The oldest settlers of central Texas still talk feelingly of the memorable drought year of 1887, but it is a fact that there was even less rainfall in 1898 than in 1887. Early in the spring cattle had been placed in the station pastures, and as long as the stock water lasted the plans for handling them, as set out above, were carefully followed, but from time to time the water supply gave out between rains, and the cattle had to be taken to other pastures in which there were streams of running water. By the end of November the effort to hold them even temporarily in any of the station pastures was abandoned.

When the garden tract (10 acres) had been planted, as stated, its only fence was 5 strings of barbed wire. Soon after the alfalfa, cowpeas, and teosinte began to grow the prairie dogs and jack rabbits from every point of the station and from the outside moved en masse to them, destroyed nearly all the alfalfa roots, and did considerable damage to the velvet-bean and cowpea vines and the teosinte. Enough seed of the cowpeas was saved for another year's trial. The velvet beans, in spite of the long-protracted hot weather and the short rainfall, made a surprising vine growth, but they bloomed and the abundant crop of pods formed too late to mature a crop of beans before the frosts of October, which were much earlier than usual for that section. The teosinte made a vigorous growth of 18 to 32 inches, when the drought began and the growth stopped, the roots being too far gone to do well when the fall rains set in. The roots survived the drought and the shoots made some growth until frost, but no seed matured.

As a result of these several garden experiments a report was made to the Agrostologist under date of November 24, 1898, in which it was suggested that with normal amount of rain during the next year it would be practicable to demonstrate: (1) That alfalfa of all kinds could be grown successfully without irrigation in central Texas; (2) that teosinte would prove a splendid forage plant for the section—in fact, superior for forage purposes to any of the sorghums as tested to date; (3) that the velvet bean would prove a crop of much value; (4) that all of the several varieties of cowpeas, which had been experimented with to date, would be shown to be available crops for forage purposes; (5) that practically no definite results had been secured so far as the grass seeds sown were concerned, only a few of the varieties having germinated, none of them having developed satisfactorily on account of the drought. It was also suggested that the work had given sufficient promise that definite, tangible results on similar lines, of much benefit to the farmers and stockmen of central Texas, would be secured as the result of further experiments. In the matter of the efforts to secure range improvement as the result of harrowing and disking three of the 80-acre pastures, it was suggested that they had proven satisfactory and justified the belief that a rapid increase in the quantity of grass on the overstocked pastures was practically assured.

This work was done during March and April, and the rainfall during May (2.60 inches) was satisfactory to the extent that notwithstanding the hot weather heretofore mentioned the grass in the three pastures was very much better than that in the station pastures not treated and in those in the same neighborhood outside of the station. In two of the pastures a disk harrow was used which every 4 inches cut furrows from 3 to 6 inches deep, as the surface of the ground was harder or softer, or gravelly, or free from gravel. In the other pasture treated an ordinary iron-tooth harrow was used, heavily weighted at times, the effect being to scarify the surface as thoroughly as possible. There was rather a heavy growth of mesquite trees growing in each of the pastures, and it was not possible, therefore, to cut into every acre of the ground.

In this connection it may be well to explain that the theory on which this work of harrowing was done was: (1) That by cutting into the ground by disk or harrow teeth the grass roots would not necessarily be injured, but on the other hand would be given a better chance for development through the looser ground below the surface; (2) the surface runners from the grasses would be given softer ground in which to take root readily; (3) the storm waters would be saved instead of being allowed to run off into the lower places, and thence into the creek beds and rivers, and the rain would go into the ground where it fell and directly to the grass roots; (4) seed beds would be made in which the grass seeds, as they fell to the ground, or were blown over the hard ground elsewhere by the winds, would be arrested and find suitable places in which to germinate.

Notwithstanding the drought of 1898, there was a very marked improvement in the conditions of the several pastures treated. During the latter part of March, 1899, just one year from the first inspection above mentioned, Messrs. Middleton, Parramore, and Bryan made a second inspection of the station and unanimously reported that the conditions during the year had improved so that the section of 640 acres, taken as a whole, had in March, 1899, a capacity to support mixed cattle at the rate of 1 head to every 10 acres, or 64 head to the section. During the next month Messrs. Middleton and Bryan made another visit to the station, again carefully inspected the pastures, and reported that the capacity of the section for mixed cattle was then at the rate of 1 head to every 8 acres, or 80 head to the section. This was after the spring rains had begun to fall and the grass was making growth. The gains as reported by the committee were phenomenal, considering the fact of the drought of 1898, being 100 per cent in a single year, and, had the station pastures been stocked during the year to their capacity, as recommended by the committee in March, 1898, it would have been fair to take the result as demonstrating the correctness of the theories underlying the methods adopted to improve the range. But on account of the droughts the pastures were not stocked nearly as heavily as had been recommended during a considerable part of the year, and it was still an open question whether the improved condition of the station pastures, especially those which were harrowed and disked, was not quite as much due to the fact that they had been rested at the season when the grass seeds were maturing and dropping as to the fact that the surface had been treated.

CONCLUSIONS FROM THE FIRST YEAR'S WORK.

At the end of the first year's station work the facts as above set out were reported to the Agrostologist, and the conclusions as submitted were:

(1) Tnat it will pay farmers and stockmen of Texas, especially in the semiarid regions of the State, to cultivate their pastures by use of disk and iron-tooth harrows.

(2) That it will pay them to rest their pastures periodically during the seasons when the grass seeds are maturing and falling to the ground.

It was believed then that the results of the station work to that time, under the conditions set out, clearly demonstrated the correctness of these conclusions, and later results have confirmed them.

HISTORY OF THE SECOND YEAR'S WORK.

EXPERIMENTS WITH VARIETIES.

The conditions under which the work was continued into the second year were very difficult. In the first place the continuous extreme cold during the months of January and February was very unfavorable for experimental work. During January the thermometer frequently indicated several degrees below freezing point, and during February there were but eight days when the temperature was above 32°. The month of January was dry, even for that section, the total precipitation being only 0.51 inch. During February it was but 0.01 inch—practically nothing—and only 0.04 inch during March. During the autumn of 1898 the 10-acre garden tract had been plowed deep with a turning plow, the purpose being to expose the earth to the freezes to follow and to save every drop of rain that might fall there.

Notwithstanding the dry weather of January and February and to March 15, this ground was in fair condition to receive seeds at the last-mentioned date. It contained but little moisture, but on account of the freezes during January and February it was easily pulverized. In anticipation of rain, planting of grass and forage plant seeds was begun March 15 and continued until May 4. During April the rainfall was about normal for the season, namely, 2.96 inches, but on account of the dry weather and the cold condition of the ground during March many of the seeds planted that month did not germinate. Those that did germinate, however, grew rapidly, and as the rainfall during May and June was all that could reasonably have been desired, everything in the garden, including the weeds, grew very rapidly. The garden had been laid off in plots 20 feet square, separated into subdivisions, according to the quantities of seeds on hand. As a rule the seeds were sown broadcast, hence it was impracticable to use plows in fighting the weeds, and in the effort to get rid of them by hand weeding much damage was necessarily done, some plants being trampled and many others pulled up with the weeds. All these difficulties were exceedingly discouraging, but they suggested methods that later were adopted with eminently satisfactory results.

During July the temperature rose to 102°, and the rainfall fell off from 5.45 inches in June to 1.38 inches. Hot winds blew nearly every day during the month, and by the 1st of August the garden plants, which up to about the end of June had been full of sap, presented the appearance of having been scalded, where they were not actually dead. During August there was but one rain, and that only 0.10 inch, on the 16th, and during September there was but 0.44 inch, on the 7th. From that time to October 16 there was practically no precipitation, and then it was only 0.01 inch, and from the 16th to the 26th the conditions were about as unfavorable as could be imagined. Nevertheless, many of the garden plants to be hereafter specially mentioned survived, and when the drought of 1898, scarcely less severe than that of 1887, was broken on the 26th of October, it was surprising how many of them were, in fact, still looking vigorous. On that date there was a rainfall of 2.89 inches, and at once the several varieties of alfalfa, sulla, sanfoin, and vetches began to green out, and between then and the early frosts of November each made an astonishing growth.

No attempt will be made here to give the details of the very many grass-garden experiments conceived and worked out with much care. That many of them demonstrated the impracticability of the methods adopted were not surprising; but, as emphasizing the necessity for trying others, these failures have special value.

Perhaps it may be well to mention the fact that part of the 10-acre grass garden was too rocky for cultivation at all, a part was too gravelly to be satisfactorily cultivated, and all of it was thin and dry.

The lower levels were drained of moisture by the bed of a small stream which ran through the east side of the garden and which only at times, after hard rains, held water. The soil extending from these levels was dry as well as thin. It was quite the usual thing for visitors to the station to notice and comment on the fact that a more unpromising spot for garden purposes could hardly have been selected, and this was in fact true; but they did not always note that this particular 10-acre tract was about as rich as the other 630 acres of the section. nor did they consider the very important fact that a line of successful experiments, secured under the most favorable conditions, would possess but small value in the estimation of the average farmer and stockman of central Texas. As above stated, the section as a whole was selected because it was not a rich body of land, as well as for the reason that as a cattle range it had been badly overstocked and generally abused; and the 10 acres included in the grass garden had been selected for the very reason that condemned it in the estimation of visitors generally, namely, because the soil was thin and dry and otherwise below the average of the garden land throughout central Texas.

It is well in this connection to suggest to farmers and stockmen who are interested in such work as was done in the station garden that if under the unfavorable conditions through which that work was prosecuted even a fair success has been secured, they should feel encouraged to experiment themselves on similar lines, having richer soils to depend on in the first place, and better seasons, as a rule, to look forward to. The normal average rainfall throughout the central Texas country being about 30 inches, it is prudent to figure on that much in making calculations for further experimental work.

During the first two years' work near Abilene the average precipitation was less than 20 inches during the first and less than 26 inches during the second—only 45.29 inches during the twenty-four months, when 60 inches might reasonably have been expected—a shortage of 14.71 inches. Nevertheless, as the following record will demonstrate, the grass-garden experiments were not barren of encouraging results.

True, of the several varieties of grasses tested most turned out poorly, but quite a number were found to be well suited to the semiarid regions. The greatest successes were secured with the native grasses, and farmers and stockmen of the section are earnestly recommended to give special attention to such grasses as side-oats grama, blue grama, black grama, rescue grass, buffalo grass, grapevine mesquite, and Canadian rye grass. Many others might be mentioned as being easily grown from the seed, but as the result of the second years' station work those enumerated gave the best results.

It is not necessary to tell central Texas stockmen and farmers that curly mesquite. needle grass, knot grass, everlasting grass, and feather blue stem are valuable and worthy of their best attention. They are all natives and old-time friends, and their values are too well known to need special mention. There are many others of equal or almost as great value with which they are not familiar, and they will do well to look into their histories and study their characteristics. Of the more than one hundred varieties of grasses and forage plants tested in the grass garden during the season of 1899–1900, each one here mentioned was demonstrated to have special value. Of the millets tested the Japanese barnyard and Shama gave special satisfaction, while the pearl, broom-corn, and German millets did very well. Of the forage plants not grasses tested the best results were secured with the annual saltbush from Australia, three varieties of alfalfa (the common lucern, Turkestan, and Oasis), two varieties of the vetches (spring vetch and hairy vetch), sulla, sanfoin, several varieties of cowpeas and soy beans, velvet bean, teosinte, and many varieties of sorghum. Of the experiments made that season with several of the clovers none turned out satisfactorily.

During the third year of station work each of the grasses and forage plants tested during the other two years was again tested, with many others, and in the statement of general results (p. 37) will be found a list, with the most important characteristics of each species tested and demonstrated to be of value during the three years.

RANGE IMPROVEMENT.

It was not until April 10 that the ground in the pastures was in fair condition for harrowing. On that date harrowing was begun, and was continued, with some interruptions, until completed. During May, June, and July the growth of the grass was thoroughly satisfactory in the pastures treated with the disk and iron-tooth harrows, and the cattle that were kept on it in the proportions recommended by the inspectors were fat, sleek, and healthy. It was never possible during the three years that the station work was continued to carry out very strictly the definite plans for treating the station pastures as originally laid down, but during the twelve months from April, 1899, to and including March 31, 1900, they were substantially met. Without going into exact details on the subject, it may he stated that, taking the year as a whole, the average number of cattle as recommended was kept in the pastures. If, on account of scarcity of stock water, the number had to be temporarily reduced, the average was well made up later when it was deemed prudent to do so.

In a general way it may be stated that during the period mentioned there were held on the station pastures an average of 80 head of mixed cattle in the proportion of 1 animal to every 8 acres; and the further fact is here suggested that at no time during the year did any of the pastures indicate that they were overstocked, but, on the other hand, it was frequently remarked by visitors to the station that even more than 80 head of stock could with safety be held on them.

At the end of the second twelve months' work, in March, 1900, the same three stockmen who had inspected the station pastures in 1898 and 1899 were again invited to make a close examination of them with the view to determine their capacity for sustaining cattle as compared with that of former years. Col. J. W. Parramore was not able to visit the station in company with Messrs. Middleton and Bryan, but about two weeks later he went over practically every acre of the section, and was impressed with the value of the treatment the pastures had received to the extent that he announced his intention of adopting similar methods in the handling of his own extensive holdings. Messrs. Middleton and Bryan also made very full and careful examinations of the station pastures, and agreed in the main in their conclusions that the harrowing and disking treatment had greatly improved the areas, though they did not quite agree in their estimates of the percentage of gain secured since their last inspection, in March, 1899. Mr. Middleton thought the gain had been fully 50 per cent in the twelve months, but Mr. Bryan thought from 30 to 35 per cent a more conservative, hence a safer, estimate.

CATCHING WIND-BLOWN SEEDS.

During this period an experiment was made that deserves more than passing notice. It is a fact well known to and recognized by central Texas stockmen that every year a large proportion of the grass seeds are lost to the ground on which they are grown and matured by reason of the fact that they are carried onto other lands by the strong winds that blow steadily during the summer months. The prevailing direction of these winds is from south to north. In order to save the seeds maturing on the station pastures, it was thought that perhaps if furrows were plowed across them about every 12 feet, say from east to west, this much-desired result might be secured. The idea was (1) that the seeds, if blown at all by the winds, would be caught in these furrows, and (2) that the storm waters that would fall in the pastures would be caught in the furrows, and instead of being allowed to waste by running into the creeks and bottoms would go to the roots of the young grass.

In May, 1899, this work was done, covering 10 acres of subdivision No. 9, next to the grass garden. By the end of June excellent results were plainly in evidence, as anticipated. The furrows had caught a great many seeds, which had gotten the benefit of surface irrigation incident to rain, also caught in the furrows. These seeds had quickly germinated and were growing vigorously, and all the grasses next to such furrows were greener and more vigorous than those farther away. The difference noted was so pronounced that in approaching that part of the station section the course of the furrows could be easily traced by the eye quite half a mile away.

TRANSPLANTING GRASS ROOTS.

During the first two years of the station work every part of the section was overrun by prairie dogs, which were not gotten rid of until the next year. There were thousands of these pests on the 640 acres of the station land. One condition largely due to them was that there were considerable areas over the section practically bare of all vegetation. It was believed that such spots could be covered by planting in them seeds of several selected native turf-grasses, viz, curly mesquite, needle grass, cotton-top, wild timothy, black, blue, and side-oats grama, Canadian rye grass (wild rye), and everlasting grass. The seeds were planted just before rains, and in every instance they grew well and contributed in a very substantial way to the improvement of the range. Those mentioned are but a few of the many pasture grasses (all natives of central Texas and to be found in practically every one of its counties) which may be used to excellent advantage in that way, and it is recommended that farmers and stockmen make similar experiments with the view to the improvement of their pastures.

BALING LEGUMES AND FODDER PLANTS.

In all the semiarid regions of the United States, including central Texas, it is practically possible to grow every year satisfactory crops of several varieties of sorghum. There is little reason, therefore, for stockmen and farmers throughout those regions not making ample provision for feeding their live stock, even during the drought years, when their grass pastures fall short or fail entirely. It is a well-known fact, however, that the methods of curing and preserving sorghum hay have not heretofore proven entirely satisfactory. Silos have not been found sufficiently cheap to commend themselves, and of the stockmen who have tried them but few have secured good results. Shocking and ricking the fodder has not been at all satisfactory, for the reason that the juices have dried up, leaving the stalks dry and harsh and the fodder light and with little food value, while outside of the drier sections it has been found impracticable to save such hay at all, for the reason that in sweating, inevitable as a part of the curing process, the hay molds and becomes rotten and worthless. In the latter instance the trouble is due to too much moisture; in the former to the fact that the air is not moist enough.

It was believed that the sorghums, and many of the other succulent forage plants outside of the grasses, might be successfully baled. and in that way preserved, with their natural jucies, for food purposes. Notwithstanding the drought, vigorous growths of several varieties of forage plants were secured, as of the cowpeas, velvet beans, teosinte, sorghums, and alfalfas. It was determined to experiment with them and also with pearl millet and the common peanut vines with the view to ascertaining whether they could be baled and in that way preserved in good condition for feeding purposes. When the cowpeas were nearly in full bloom, and before they began to turn yellow, the vines were cut and carefully cured as for hay. Velvet-bean vines, with pods on them, but in a very immature state, were also cut, cured, and stacked. Some of the smaller teosinte stalks, which had survived the drought, were also cut, cured, and placed in shocks. Several varieties of sorghums were cut and cured when the stalks were tender and the heads in the "dough" state, and bundles of alfalfa and pearl millet were also prepared for baling. During the season all of these stuffs were baled and the bales packed away under a shed to await developments. After several months a bale of each of the stuffs was opened and examined, and in every case the hay was found to be as sweet as when first baled.

It is recommended that the stockmen and farmers of central Texas and of the Southwest generally test the value of this method of preserving the coarser forage grown on their own ranches and farms.

EXHIBITS AT FAIRS.

In the autumn of 1899 a collection of bales of hay grown on the station, including some of the baled forage plants above mentioned, was sent to the Division of Agrostology, Washington, D. C., where they were included in the general exhibit sent by the Department of Agriculture to the Paris Exposition of 1900. The Agrostologist stated that they made a very interesting and valuable part of the Government exhibit. Duplicates of the collection, with the addition of a few bales of grasses grown in the Abilene country, but not on the station grounds, were made up into an exhibit and turned over to the managers of the district fair held in Abilene in October, 1900. The display attracted much favorable attention from the large number of stockmen and farmers present, many of whom were led to take an interest in the later station work.

SUMMARY.

At the end of the second year's station work the foregoing facts were reported to the Agrostologist with a general estimate as to the results secured. In the report it was asserted that notwithstanding the adverse conditions under which they had been conducted, many of the experiments made during the year had yielded results of substantial value. They had demonstrated the availability of the alfalfas, sulla, sanfoin, the vetches, several varieties of cowpeas, velvet bean, soy bean, teosinte, and several varieties of sorghum for annual or temporary pastures and for hay purposes. They had shown the possibility of utilizing to good advantage, for permanent pasture purposes, the seeds of such grasses as the gramas, mesquites, wild timothy, cotton top, Canadian rye, and everlasting grass. They had definitely proven that range improvement could be secured by judiciously resting the pastures, by cultivating the sod, and by sowing the seeds of hardy native and improved grasses. These and the other results secured had satisfied many stockmen and farmers that, at comparatively small expense, they could greatly improve their ranges, and that by the cultivation of many excellent grasses and forage plants, up to that time known to them only through their books and papers, they could add very much to the productive capacity of their ranches and farm pastures.

HISTORY OF THE THIRD YEAR'S WORK.

WEATHER CONDITIONS.

From April 1, 1900, to and including the month of March, 1901, when the station work was concluded, the conditions in the main were satisfactory, as were the results secured. Notwithstanding the difficulties experienced during the former two years, enough had been accomplished to give substantial results during the next twelve months.

As stated above, many of the experiments made to date had proven failures, but they had suggested and opened up the way for the adoption of better methods. Of the other experiments some had been in part successful, while still others had proven entirely satisfactory. With two years' experience, and the record well in hand as the basis for future work, that work was begun under very encouraging conditions.

The seasons throughout the twelve months, while not all that could have been desired, were good and in striking contrast to those of the preceding twenty-four months.

During April there was abundant precipitation—5.43 inches—which put the grass-garden land in excellent condition to receive seeds and the pasture lands in like condition to be cultivated and otherwise handled. During May the rainfall was 4.11 inches, which was very favorable to the growth of the garden stuffs and pasture grasses. The temperature during these two months was normal, hence satisfactory. By June 1 a large number and variety of seeds had been sown in the grass garden, and good stands of practically everything planted had been secured. The pastures selected for special treatment, as set out in the original plans, had been disked, and, owing to the abundant rains and the favorable temperature that followed, the grasses in them were developing rapidly; and the grasses in the other pastures were green and vigorous to such extent that it was considered safe to hold on the entire 640 acres of pasture land not less than 85 head of mixed cattle. During June the rainfall was only 0.30 inch and the temperature was at times extremely trying, ranging from as low as 63° to as high as 105°, but nothing suffered very materially. During July and August the rainfall averaged about normal, being, respectively, 2.59 and 2.11 inches, while the temperature ranged from 65° to 96° during the former and from 64° to 100° during the latter month. In September the precipitation was much above normal, and was 9.6 inches during October. Throughout these two months the temperature continued satisfactory for the work in hand. During the next three months there was a decided falling off in the rainfall, which was but 0.30 inch in December, and but 0.03 in January. This shortage, however, which would have resulted in much damage to every kind of vegetable growth had it come during the normal hot weather of June, July, and August, did not seriously interfere with the grass-garden stuffs nor with the pasture grasses. Hence it was that in February, 1900, it was manifest that the year's work had been successful to that date, and promised to prove entirely satisfactory for the full twelve months, and so it turned out.

The weather during February was good, the rainfall being 1.44 inches, and the temperature averaging 43°, there being but a few days in which there was any freezing weather. In March the precipitation was 0.72 inch, and the temperature all that could reasonably be desired, its range being from 23° to 88°, the mean being 56°—strictly normal. The precipitation during the twelve months was 31.31 inches—something above the normal.

In view of these facts only good results were to have been expected, and this expectation was realized, as will be shown.

In this connection it may be well to state that the above details as to the weather during the twelve months are here given for the reasons (1) that those interested in farming and stock raising in central Texas may be advised as to what are normal weather conditions in the section; (2) that their special attention may be called to a general fact, namely, that two comparatively unfavorable seasons are very likely to be followed by one at least that is specially favorable; (3) that although the section has been in the past, and in the future is likely to be, afflicted periodically with droughts, extending over considerable periods of time, it is not impracticable during such periods to work out good results on the lines attempted on the grass and forage plant station near Abilene, Tex. Taking an average period of three years, it is practically certain that excellent results can be depended on if correct methods, based on correct ideas, are pursued. The farmer and stockman who is prepared to give up his experimental work because of a few or several failures, during unfavorable seasons, had better not go into experimental work at all, as he is certain to experience them. He who is prepared, on the other hand, to expect such failures, under such conditions, but has the courage to push on in his experimental work, whether successful or not, through an average period of three years, is almost certain to secure results that will abundantly repay him for his expenditure of time, labor, money, and patience.

It would be difficult to imagine more unfavorable conditions than those which existed for such work as was prosecuted on the Government station near Abilene during the first two years, but by persistence, and taking advantage of the lessons forced on those engaged in it, final results were secured which amply compensated for all the trials and tribulations experienced. The central Texas stockman and farmer who will lay out for himself a three years' plan for experimental work with a view to range improvement, and will persevere through any three years, will succeed.

GRASS-GARDEN WORK.

One of the lessons learned from the former year's work was that for experimental purposes it was not best to sow any seeds broadcast, but in drills with space sufficient between the drills to admit of cultivating. Hence it was that when the season for the third year's work came on this plan was adopted and carried out to the entire satisfaction of all parties interested. As in the autumn of 1899 the garden ground (except where certain perennials, such as the alfalfas, sulla, sanfoin, and the vetches, which, having been originally sown in plots, were not to be disturbed) had been broken as deeply as practicable in the fall of 1900, in order to catch and hold the fall and winter rains and get the full benefit of the winter frosts. It may not be out of place in this connection to state that as a result of this treatment, when the time arrived to begin the spring planting, the ground was in excellent condition to receive seeds.

A FAILURE NOTED.

During the month of January, 1901, a line of experiments was tried that promised good results, but turned out, in a sense, disappointing. It had been noted that the alfalfas and clovers, especially the latter, sown during the spring months in the former years had suffered very much during the hot weather of May and June and through July, and August. It was thought that if these seeds were sown at the same time and together with such grains as wheat and rye the young plants would be protected from the hot sun by the higher stalks of the latter. Carrying out this idea, 83 rows of several varieties of rye, barley, and winter wheat, each mixed with seeds of one of the alfalfas or clovers, were planted. For instance, red-clover seeds were mixed with several varieties of wheat, rye, or barley; and in like manner other clover and alfalfa seeds. This work was begun January 4 and was continued up to and including January 31. In nearly every case a fair stand of grain was secured, but in a large proportion of the cases the stands of clover and alfalfa were unsatisfactory, which was perhaps due in the main to the fact that, in order to put the grain seeds deep enough in the ground, the smaller seeds were buried entirely too deep. However, in practically all the rows planted some of the smaller seeds germinated, but in not a single case did the plants grow vigorously. By June 1 in spots only was it noticeable that any of the clover or alfalfa plants were alive, while the rye, barley, and wheat grew and developed well. Later, during February, and as late as during the early days of March, alfalfa and clover seeds, mixed with several varieties of spring wheat and oats, were sown, but, as in the other instances mentioned, only indifferent stands of the alfalfas and clovers were secured, and, while the uniformly excellent stands of oats grew and matured well, in no instance did the others do so.

These experiments, while they may be regarded as suggestive, are not to be taken as conclusive against the idea of mixing the smaller seeds with the larger, but they justify a substantial doubt of the practicability of the idea on which the experiments were based. If clover and alfalfa seeds be sown on ground previously seeded to any of the grains mentioned, after the latter are up, it is quite possible, even probable, indeed, that good stands might be secured, and the plants grow well. It is practically certain that such of them as did so would be much benefited by being protected by the older and larger growths from the direct rays of the hot summer sun and the hot winds. The smaller seeds might be sown on the surface and covered by means of a light harrow where the others had been broadcasted; or where the others had been drilled the smaller seeds might be drilled between rows at proper depths. In either case no serious injury need result to the young rye, barley, or wheat; but on the other hand, the probabilities are that this surface treatment of the ground would materially benefit them by killing the weeds, loosening the surface, and inducing the absorption of moisture from the air—something nearly always to be desired during the hot months in the semiarid regions.

A TENTATIVE SUCCESS NOTED.

Another experiment on somewhat similar lines may be noted. Several varieties of beans and peas having running, clinging vines, as cowpeas, field peas, and velvet and other running beans, were sown in the same rows with many varieties of sorghum. In some of the rows the peas and beans were sown with the sorghum seeds, in others when the sorghum stalks were several inches tall. In every instance satisfactory results were secured.

EXPERIMENTS WITH GRASSES.

A large number of sowings of grass seeds were made between March 28 and April 8. Practically everything that had been tested in the two former years was again tested, with many others. In the list hereafter given will be enumerated such grasses as, in the tests made, were shown to be worth cultivating in central Texas.

NATIVE GRASSES THE BEST.

As a general rule, the native grasses did very much better than the others, and the recommendation is made to central Texas stockmen and farmers that they place less reliance on the oftentimes extravagant claims made by interested dealers in seeds, etc., as to imported grass and forage plants, and devote more attention and time to those native to their respective sections. True, many valuable additions to our native plants are the results of intelligent importations from other countries and from one section of our country to another; but experimental work with foreign grasses, etc., is very likely to prove disappointing, while there is every reason to expect good results from the cultivation of good native varieties. It is not necessary to go outside of the Southwest, or of central Texas, indeed, to find a large number of native grasses quite equal in every way to the very best of the foreign varieties that have been so industriously advertised by dealers and in the public prints. Professor Lamson-Scribner reports that there are from 800 to 900 distinct varieties of grasses native to the United States. More than 25 per cent of these are native to Texas, and within the comparatively limited territory included in what is being considered as central Texas, nearly, if not quite, 200 species are to be found, to say nothing of the large number of native clovers and other forage plants, exclusive of the grasses.

With such natural resources practically at their very doors, central Texas stockmen and farmers need not look to foreign countries, or to other States, or even to other sections of their own State, for grasses and forage stuffs that may be cultivated to the best advantage. On every natural range about them, growing on their farms, along the fence rows, and wherever else they are allowed to grow, are such as are peculiarly adapted to the conditions of soil and climate that obtain in the section. They are where they are because the soil and climate are favorable, and no experimental work is necessary to determine their adaptability and general value.

EXPERIMENTS WITH THE COARSER FORAGE PLANTS.

During this third year of station work practically every test made in the former years with the coarser forage plants was repeated and many were made with others. In the list of forage plants recommended for central Texas will be enumerated such as were found to be intrinsically valuable and adapted to the climate and soil conditions of the section. In a general way it may be stated that each of a number of varieties of sorghum was successfully grown. Some of them were found to be better than others for fodder purposes and others were found to be better grain producers. Some matured earlier than the others, and all matured seeds satisfactorily with the single exception of teosinte, and that was shown to be very valuable as a coarser hay product.

RANGE IMPROVEMENT.

TRANSPLANTING GRASS ROOTS.

In the spring of 1898 roots of a large number of grasses found growing on or near the station section were taken up and planted in the grass garden, the purpose being to determine which of them could be utilized to advantage in efforts to cover the large number of entirely naked spots in the station pastures. Most of them gave entirely satisfactory results. In the course of the next (second) season's work this line of experimental work was very much extended, with like success. Again, during the third year's work, still other grasses were tested in the same way and for the same purpose; and the list given hereafter includes such as were found to have special value in that direction. Of the sod or pasture grasses, each of the following gave good results: Barnyard grass, Bermuda, big blue stem, black grama, blue grama, brown sedge, buffalo grass, crab grass, curly mesquite, dogtown (needle) grass, everlasting grass, galleta, grama grass, redtop, rescue grass, bur grass, side oats grama, Texas millet, white top, wild rye, and wild timothy. It may be safely stated that any and all of these species will bear transplanting, and farmers and stockmen who have bare spots scattered over their pastures, due to the ravages of prairie dogs, ground mice, and other like grass destroyers, need not hesitate to use them to quickly cover such spots. The sods may be taken up and transplanted in the early spring when the spring rains may be looked for with reasonable certainty, or in the early autumn when the rains are most likely to begin. During the month of September or October of each year, as a rule, good rains may be expected throughout central Texas. If the rainfall be less than normal during September it is very likely to be above normal during October; and if it be more than normal during the former it is not very likely to be up to normal during the latter month. In 1898 (as hereinbefore stated) the precipitation was 3.44 inches during September, with only a trace in October. In 1899 it was only 0.44 inch in September and 2.90 inches in October. In 1900 the aggregate for the two months was abnormally large, being 9.65 inches during the former and 4.39 inches during the latter month. The old-time saying that "all signs fail in dry weather" applies as well to central Texas as to any other section, but one can determine several hours, and sometimes two or three days, in advance about the time when a good rain is going to fall. The tests made in the course of the station work showed that very few of the sods died when transplanted two or three days in advance of good rains, either in the early spring or autumn months.

THE CULTIVATION OF PASTURE GRASSES.

As already stated, the reports made by Messrs. Middleton, Parramore, and Bryan show that at the end of the first twelve months' work substantial improvement had been secured, and that at the end of the second year's work the gain in the two years had been quite 100 per cent, notwithstanding the very distressing drought of 1898 and the scarcely less protracted and severe spell of 1899. The same character of treatment of the same pastures was continued in 1900. In the early spring of that year the harrows were started, the disk in pasture No. 2 and subdivision No. 9. In the former year the disk had been set so as to cut very nearly in a straight line and not more than 3 to 4 inches deep. In this second year the lever was thrown forward so as to give to the disk an additional curve, and weights were added with the view to forcing the disks quite 4 to 5 inches deep, and so loosening the ground below the grass roots. In pasture or subdivision No. 7 there was so little grass or weeds on the ground when the first harrowing was done in 1898 that it was not difficult to force the teeth into the ground without weights. The next spring practically every acre was covered, more or less, either with grass or weeds, largely the latter, and in consequence the frame of the harrow had to be weighted. To that end heavy logs were fastened on top of it, but it was found necessary to go over and over some areas where the grass and weeds were thickest and rankest. The third spring it was found that the further use of the iron-tooth harrow was no longer practicable. On every part of subdivision No. 7 there was a comparatively heavy growth of grass or weeds, now largely the former, and no possible weighting of the harrow frame could force the teeth sufficiently deep into the ground and hold them there to do any good in the way of scarifying the surface and loosening the earth about the grass roots. Hence it was that the iron-tooth harrow was discarded and the disk harrow used instead on all three of the treated pastures. In order to secure what was expected to produce the best results, the lever was moved forward still further than in the year before, weights were placed in the disk-harrow frame, and the ground was cut from 5 to 6 inches deep and more decidedly loosened than before to that depth. In the later summer and early autumn months of 1898, and again in 1899, young grass roots were noticeably abundant all over the cultivated pastures. As this was not nearly to a like extent the case in the several pastures which had not been treated, it was taken to mean that these numerous young grass roots were in direct consequence of the special treatment given to the three pastures specified.

In the spring of 1900 Prof. Thomas A. Williams, Assistant Agrostologist (now deceased), visited the station and made a very painstaking and thorough inspection of every part of it, including the pastures. He was specially satisfied with the evidences mentioned of the value of the surface cultivation of the pastures, and was very positive in the expression that such evidences of the successful application of the theories on which the work was predicated were convincing. Later, in March, 1901, Prof. C. L. Shear, who in the meantime had succeeded Professor Williams in the office of Assistant Agrostologist, made an official visit to, and inspection of, the station. The effort was made during his visit to again have an inspection of its pastures made by Messrs. Middleton, Parramore, and Bryan, but Colonel Parramore was absent on his own ranch in another county, and Mr. Bryan was in Austin in attendance on the Texas legislature. In company, however, with Mr. Middleton and the special agent in charge, Professor Shear went over the pastures very carefully and thoroughly, and concurred fully with Mr. Middleton's expressions of opinion that the three cultivated pastures, in many ways, were much better than any of those not cultivated. Not only did they have on them more grass, but the variety was greater, and the grass was distinctly of a brighter color and more vigorous looking. Before the return of Messrs. Parramore and Bryan to Abilene the term of the Merchant lease of the station section terminated and the three years' work was brought to a finish; hence no final inspection of the pastures was made by the original committee. Mr. Middleton made a report in which he stated that, as a result of his several inspections of the said pastures in 1898, 1899, and 1900, and again in 1901, he was certain that in the three years ending March 20, 1901, their capacity for sustaining stock had been considerably more than doubled—a result attributable distinctly, in his opinion, to the treatment they had received in the matter of cultivating some of them, as stated, and in the systematic resting of all of them according to the original plans. During the last week of March, 1901, a special committee of three well-known farmers, who owned farms and pastures in the immediate neighborhood of the station, and who, during the entire three years, had taken deep interest in the work and had watched it closely, were requested to make, and did make, a final inspection of the station pastures. They stated in their report that they had been well acquainted with the land included in the station during all of the three years it had been in the hands of the Department of Agriculture, through its special agent, and that, as the result of the treatment of the tract under his direction, the capacity of the pastures for sustaining live stock, year in and year out, without other food than such as was afforded by the pastures themselves, was considerably more than 100 per cent greater at the end than at the beginning of the three years' work.

SUMMARY.

CATTLE HELD ON STATION PASTURES.

It will be borne in mind that in March, 1898, the capacity of the 640 acres included in the Merchant lease was estimated by experts as being for mixed cattle at the rate of 1 head to every 16 acres—about 40 head altogether. During the third year of station work from 80 to 85 head of mixed cattle were held in the pastures, in the proportion of about 1 head to every 7½ acres. At times the proportion was even greater, as it frequently happened that in addition to the cattle several head of horses and mules were allowed the run of the pastures. At no time, however, were the stock permitted to graze all of the pastures at the same time. The effort was made to give each pasture periods of rest in regular succession. That meant the doubling up of the stock in the pastures in which they were being held; hence it happened that during considerable periods of time the different pastures were carrying quite double as many animals as the average recommended by the inspectors. As one result of this systematic resting, the grasses in each pasture were, to a greater or less extent, permitted to mature seeds, which, falling to the ground, increased the number of grass roots and in that way added materially to the capacity of the range for supporting stock.

If Mr. Middleton and others of the stockmen who entered the country first with their cattle are correct, namely, that originally all of that section had a capacity to sustain stock equal to 1 head to every 3 or 4 acres, it is evident that the station pastures have not yet been brought back to their original capacity. What has been accomplished, however, justifies the belief that if like methods on the general line of those pursued during three years to April, 1901, be followed during the succeeding three years, as a result of the six years' work the gain will aggregate several hundred per cent. Results quite as satisfactory are certainly practicable as to every pasture in central Texas. Where but 40 head of cattle are now being held it is possible to continue to hold as many on the pastures during a first year's work and at the same time much improve them. During the second year the work of range improvement may be continued, and the number of cattle on the pastures may be increased. During the third year the number can be still further increased and the work of improving the pastures still continued. The work may be continued year after year, the work each year being proportionately greater than that of the year before; and each year the proportion of cattle may be increased. An interested stockman of Taylor County submitted the inquiry: "Do you Government station men believe that the overstocked and almost ruined grass sections of this country may be brought back to their capacity for supporting cows as back in the sixties and seventies?"

The reply was given with every confidence in its absolute correctness: "It is not only possible, but each year while it is being done cattle may be held on the pastures, the proportion increasing year after year as the capacity of the pastures to sustain them shall be increased." It was practicable April 1, 1901, to place as many as 100 head of mixed cattle on the 640 acres included in the grass and forage plant station near Abilene and hold them thereon during the succeeding twelve months without giving them other feed than they could get for themselves. But that could not be done with the 640 acres thrown into one pasture and the 100 head of cattle allowed during the twelve months to range at will over the entire pasture. It pays to build and keep up pasture fences, and every stockman should see to it that instead of one or two large pastures he should have a number of small ones, some of which can be resting while the others are doing, perhaps, double duty.

THE MATTER OF COST.

In reply to frequent inquiries submitted by interested stockmen and farmers, facts and figures have been given out from time to time as to the cost of cultivating the pasture lands. If, as many suppose, such work meant an outlay of $2 to $3 per acre per year, it would mean that but few pasture owners would take such work in hand. The actual cost to the Department of Agriculture of having the station pastures cultivated can not be considered as fairly determining what the cost of similar work will be to pasture owners. The Department owned no horses, did not employ men to do the work, except from day to day or from week to week, hence had to pay more for the labor in proportion than farmers and stockmen are in the habit of paying for labor by the year. It was estimated that a man working steadily with a disk harrow could go over an average of 12 acres per day and do the work thoroughly. The prices paid were: For two-horse team and driver, $2.50 per day; for three horses and driver, $3, and for four horses and driver, $3.50. At times when there was plenty of work and labor was in demand higher prices had to be paid, but those named were about the average for the pasture work. Taking the highest price, as above, as a basis for calculating the cost of cultivating the station pastures, it would mean a trifle less than 30 cents per acre per year; for the three years' work, 85 to 90 cents. In fact, the cost to the Department did not average 25 cents per acre per year. Taking these figures as the basis of the calculation, it means that a 640-acre pasture would cost $160 per year, or $480 in three years. If the gain in the capacity to sustain stock should equal 100 per cent, it would mean that the income-producing value of the land would be doubled. If the value of the land for pasture purposes should be $5 per acre at the beginning of the three years' term, it would mean that it would be $10 per acre at the end of the term. In other words, if the value of the 640 acres, for pasture purposes, should be (at $5 per acre) $3,200, it would be at the end of the three years' term (at $10 per acre) $6,400. If these figures do not quite satisfy stockmen and farmers having pasture lands greatly needing to be improved, the additional suggestion is offered that if, on the 640 acres, at the beginning of the three years' term, it should be practicable to hold only 40 head of mixed cattle, in the proportion of 1 to every 16 acres, and at the end of the first year the gain in range capacity to sustain stock should be only 33⅓ per cent, it would mean that during the next year about 53 head of cattle could be held on the same 640 acres. If the gain during the second year should be a further 33⅓ per cent, it would mean that about 70 head could be held in the pastures the next year. If the gain during the third year should be as great proportionately as during the first and second year, it would mean that about 93 head could be held at the end of three years on the pastures that three years before could only support 40 head. How can central Texas stockmen and farmers make money more certainly or more rapidly than by working systematically and patiently on the lines suggested? They have their own horses and will not have to hire teams to pull their harrows. They have laborers hired by the year, or they can do their own work, hence will not have to pay out anything extra for having the work done. The best times for doing the work (in the early spring or the early autumn months) are the seasons when such work can be done at odd times, when other work on the farms or ranches will not be pressing for attention.

Is it worth the effort? Do the probable large gains justify the cost?

Perhaps it will be more prudent to make a trial test on a smaller scale. On that idea the suggestion is offered that those having pastures needing reclamation make such trial tests, beginning next autumn or in the following spring. Suppose a small pasture be fenced off from the general pasture, and it be cultivated one year, and during the year it be grazed and rested alternately in periods of, say, three months, the pasture to do double duty during the periods it is pastured. If at the end of one year, the seasons having been normal, there be a manifest gain in the capacity of the pasture to sustain stock equal to 30 to 40 per cent, and if the other and larger pasture shall not have, during the same period, gained in such capacity, will not such results clearly justify a second year's experimental work, with the same small pasture, on similar lines? And if that year's work shall result as satisfactorily as that of the previous year, will the result not fairly demonstrate the advisability of still another effort to restore the pasture to its original capacity for sustaining stock?

It is confidently believed that those who will take such work in hand

and continue it intelligently and systematically through three years, on even small proportions of their ranges, will need no other arguments than the results themselves to induce them to adopt and pursue to the end like methods as to all of their run-down pasture lands.

HAY AND PASTURE PLANTS RECOMMENDED FOR CENTRAL TEXAS.

As the result of the experimental work conducted at Abilene, the following list of the grasses and forage plants that may be relied on as being well adapted to the climatic and soil conditions of central Texas has been prepared for the benefit of those who may desire to improve their ranges and are willing to undertake and prosecute the necessary work:

GRASSES.

Barnyard Grass (*Panicum crus-galli*).

This erect, leafy grass, known locally also as goose grass and sour grass, is found in nearly every State in the United States in barnyards and waste grounds and in very rich, moist soils. Where it has been studied it is recognized as having a definite value, both as a pasture and as a hay grass. In "Southern Forage Plants" (Farmers' Bulletin No. 2, United States Department of Agriculture) it is described as coarse and succulent, not easily cured into hay, quite valuable for soiling and for the silo, yielding heavily, and producing an unusual amount of seed. In some sections of Mississippi and Florida it is said to be a volunteer growth that makes a good hay, which is preferred to the best corn fodder by farmers who have thoroughly tested it. In Bulletin No. 87 of the Experiment Station of the Kansas State Agricultural College it is very favorably referred to as a forage grass. It first came into notice in central Texas about 1893, when it made its appearance in the cultivated fields or about old barnyard buildings in several of the counties. It grows in bunches 2 to 4 feet high and makes a great deal of fodder that is relished by cattle, both in its green state and when cured. It has many small roots that grow near the surface, and is a strong feeder. Seeds gathered near the station were sown, good stands were secured, and a vigorous growth was made. No difficulty was encountered in the efforts to cure it, and the hay, which was light for its bulk, was successfully baled. It is an annual, but readily reseeds itself. Of the several varieties now being cultivated in the United States, one known as Japanese barnyard millet was tested thoroughly in the station garden in 1899. The ground had been broken deeply in October, 1898, and seeds were sown March 15 following in thin hillside land. A good stand was secured, and by April 18 the ground was well covered. June 3 the grass was quite 3 feet high and an excellent yield was secured, and July 1 a second cutting was made. A third cutting would have been secured had not the July drought of that year prevented. Tests made again fully confirmed the good opinion formed of the grass as the result of the former test. It will pay central Texas stockmen and farmers to cultivate the native and the improved varieties mentioned.

Bermuda Grass (*Cynodon dactylon*).

This creeping perennial grass is found in the United States from Pennsylvania southward to Florida and westward to Texas and California. It is not a native, but has been so long grown in Texas that it has become one of its distinctive grasses. It was introduced into southern Texas sixty to seventy years ago, near the mouth of the Brazos. From that beginning it has been taken to all parts of the State, and everywhere it has proved itself a valuable addition to the native grasses. It is propagated, in the main, by cutting up the roots or sod into small pieces, which are planted broadcast, or from 1 to 3 feet apart in shallow furrows. In central Texas it is extensively used for lawn purposes, as it makes a close and smooth sod. As even a moderate frost kills it down, it is not a very valuable winter grass; nor is it one of the best grasses for the high lands or prairies of central Texas, as its drought-resisting qualities are not strong. It is in this particular far inferior to curly mesquite or buffalo grass. If grown in low, moist places, it furnishes more and better grazing than either, and also produces an abundant crop of an excellent quality of hay. Several tests were made in the station grass garden to determine whether it could be propagated successfully by sowing seeds imported from the West Indies. Sowings were made in October, 1898, and in January, March, and April, 1899. Of the first two sowings not a seed germinated. A few of those sown in March germinated, but the plants soon disappeared. A rather thin stand was secured as a result of the April sowing, but when the August hot winds and dry weather came on, the roots began to give way, and by October 1 all were dead. As it is justly regarded as an excellent soil-binder, it was thought advisable to use it for strengthening the dams of the two station tanks, and in 1900 seeds were sown on the surface in March and raked in with a hand rake; but only a few plants appeared, and after a short time they disappeared. A few roots that were planted in April grew vigorously and soon made a close, compact sod. Central Texas stockmen will do well to establish Bermuda grass pastures, especially for their home calves and other stock, and if established in rich and moist soils, the most satisfactory results may be expected. As it is difficult to eradicate when once established, and spreads rapidly by means of numerous surface runners, it is not deemed advisable to locate pastures near lands intended for cultivation.

BUFFALO GRASS (*Bulbilis dactyloides*).

This is a low, fine-leafed, and extensively creeping perennial, similar in its habit of growth to Bermuda. It is found in the dry prairies as well as in the river bottoms as far north as Minnesota, as far west as South Dakota, and east and south throughout many other States, including Colorado, Kansas, Arkansas, and Texas. It is a very common grass throughout central Texas, where it is often mistaken for grama grass. Liberally mixed with curly mesquite and needle grass, the combination makes an ideal pasture. It is not one of the richest fat-producing grasses, but being a native, peculiarly adapted to the conditions of soil and climate, and affording abundant pasturage, it is one of our most valuable species. It is in no sense a hay grass. It forms a beautiful, closely interwoven turf, with lateral, creeping root stalks which bear an abundance of leaves, but it never grows high enough to be cut. It can be grown readily from the seed, but owing to the manner in which its seeds are produced it is impracticable to gather them in quantities. As the grass is easily propagated by dividing the turf and sowing the bits in furrows, it is not difficult to get a good stand of it, and, as it will survive almost any degree of dry weather, of trampling, and other ill usage, it is deservedly one of the favorite grasses of the central Texas stockmen. Several tests were made with it on the station grounds to determine its true value. A few seeds were secured, and plantings were made in October, 1898. A fair stand was secured, and the young grass roots stood the drought of 1899 well. In 1900 roots were planted and not only lived, but grew well and spread rapidly, soon covering comparatively large spots in the grass garden and in the station pasture.

BUSHY BLUE STEM (*Andropogon nutans*).

In every county of central Texas this excellent hay grass may be found. It is a tall, rather coarse grass, which is cured with but little difficulty, makes a good hay that bales well, and in that shape has good keeping qualities. It was tested fully in the station grass garden with satisfactory results. Roots dug up where they grew in rocky places and also in the open prairie were put in the ground in the grass garden, grew readily, and demonstrated the value of this grass for quickly covering naked spots in pastures by transplanting the roots. Central Texas stockmen report that they have had satisfactory experiences with the same grass in the Dakotas and in the Territories of Arizona and New Mexico.

COLORADO GRASS (*Panicum texanum*).

The writer has met with and has known this grass many years, first in the valley of the Colorado, near Austin, Tex., later in Tom Green County, in the valley of the Concho, and more recently in several counties of central Texas, including Taylor County. It is not certain where it originated, but it has been during many years past one of the best known and most valuable grasses in each of the several sections mentioned. In the Colorado Valley it made its appearance each year about the time the corn crop was ready to be laid by, when it would cover the fields, and the hay and grass would be almost as valuable as the corn crop. In the Abilene country (Taylor and adjoining counties) farmers regard it as by all odds the best hay grass. It produces large quantities of seeds that germinate well, and the growth of the grass in the late summer and early fall is astonishingly fast. Tests made in connection with the grass-garden work were in every way satisfactory. It was clearly demonstrated that this grass is easily propagated from the seed, does not become a weed, makes a great deal of splendid hay that is readily cured, and keeps well either in bulk or in bales. It has much the habit of crab grass, but is coarser, and does not become a nuisance in the cultivated fields, as the crab grass often does. Then, too, it is easily gotten rid of on the farms, which can not be said of crab grass. As a hay grass it ranks with the very best throughout central Texas. (See fig. 2.)

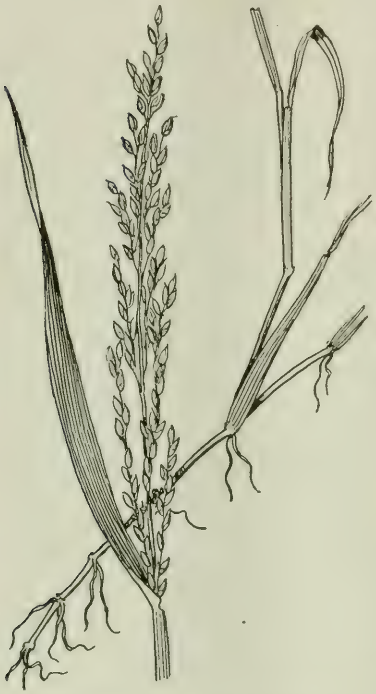


FIG. 2.—Colorado grass (*Panicum texanum*).

COTTON TOP GRASS (*Panicum lochnanthum*).

This is not a very common grass in central Texas. It is to be found in all of the counties, but only here and there in cultivated fields. Only a few seeds were gathered, and they were sown in drills in the grass garden and germinated satisfactorily. The long dry spells in 1899 and 1900 operated much against the growth, but it grew fairly well. Under cultivation it did not develop as satisfactorily as did the few volunteer bunches that were not cultivated. The latter grew to be about 2 to 2½ feet high, the bunches were rather large, there was an abundance of leafage, the stems were not large or harsh, and the seed crop was fairly good. No difficulty was experienced in curing the grass, and the hay, though light, was excellent in quality and much relished by stock to which it was fed. It is a good hay grass for central Texas, but not equal in value to some others herein discussed.

Crab Grass (*Panicum sanguinale*).

Farmers of central Texas are divided in their opinion as to this grass. Some of them claim for it that it is very valuable both for pasturage and hay purposes, while others insist that it is more of a nuisance than a blessing, as it reseeds itself, makes its appearance in the cultivated fields before the crops are matured, and absorbs the moisture in the ground to an extent which prevents the best development of the cultivated crops. It is not necessary in this connection to go into the discussion of these differences of opinion. That crab grass does furnish a large quantity of good pasturage and a good quality of hay without cultivation is an undisputed fact, but it is a question whether it injures the cultivated crops more than it is worth to the farmer. As farmers throughout the semiarid regions are frequently short on stock food, and crab grass, as a rule, can be relied on to furnish a large quantity and a good quality of grass for pasturage purposes and for hay, there are sound reasons for the belief that it would pay central Texas stockmen and farmers to devote fields to this grass. A volunteer crop that grew on a neighboring farm was cut, cured and baled, and when the bales were opened several months later the hay was found to be sweet, and was greedily eaten by the cattle and horses to which it was fed.

Curly Mesquite (*Hilaria cenchroides*).

Ask average central Texas stockmen which are the best pasture grasses, and the chances are most of them will say curly mesquite, buffalo grass, and needle grass. It is a fact that when these stockmen are discussing their pastures, they are specially pleased if they can truthfully claim for them that these three grasses, in quantities, are to be found in them. The grama grasses are no less valued by them, but none of them are in sufficient quantities to make them such important factors in the make-up of the pastures as the others named. As between the curly mesquite and the buffalo grass, a large majority, it is believed, regard the former as being more valuable, all things considered. It commences to grow earlier in the spring than the buffalo grass, makes a thick, compact turf for summer grazing, matures on its roots, holds its own under almost any amount of rough treatment, such as trampling and heavy stocking, and continues green and growing when even the buffalo grass and the gramas show the effects of the long dry spells of weather that are characteristic of all the section. During such times the leaves and stems dry up and look dead, but after a warm rain they green out rapidly. Sods of curly mesquite were planted near sods of Bermuda grass to test their respective values as turf makers. As long as the rains came regularly the latter made a better growth than the former, but when the hot and dry weather began, the curly mesquite held its own very much better than the Bermuda, and in midsummer clearly demonstrated its great superiority as a drought-resisting grass. As it is easily propagated from the roots, which, cut into bits, may be harrowed or heeled in the ground after the early spring rains, it is justly regarded as one of the best of all the native grasses of the section for use in renovating the ranges. As it never grows tall enough to be cut, it is suitable only for pasture. (See fig. 3.)

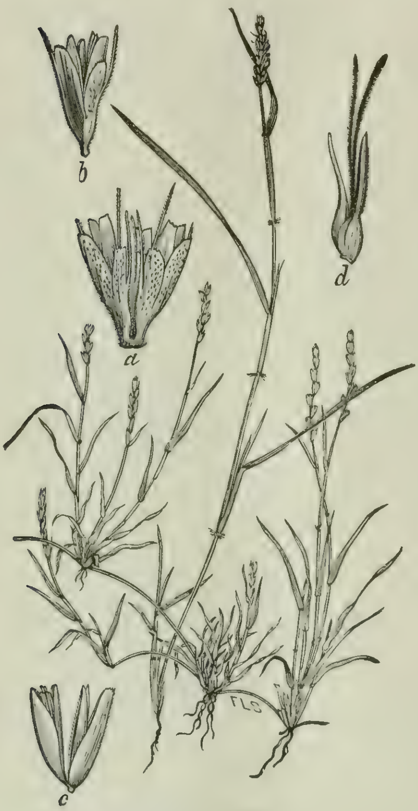


Fig. 3.—Curly mesquite.

Everlasting Grass (*Eriochloa punctata*).

This is the native grass that was the main reliance of cattlemen for hay in the early history of central Texas as a stock country. When old Fort Griffin, in Shackleford County, was a United States Army post, this grass was about all that the large number of cavalry and other horses there had to rely on for winter "roughness." In the seventies and eighties it grew all over the section from 2 to 4 feet high, in quantities sufficient to enable a great deal of an excellent quality of hay to be secured. Now it is a rare grass in the pastures, largely due to the fact that it will not flourish under such rough treatment as the ranges of the section received while "free grass" was the rule. In pastures not overstocked, along the fence rows, and at the ends of the rows in cultivated fields, it is now to be found in most of the central Texas counties, and always, under such conditions, the most permanent and promising grass in sight. As it makes a vigorous growth under favorable circumstances, and furnishes an abundant yield of a comparatively soft and very nutritious hay, it should be cultivated by stockmen and farmers. Seeds of this grass sufficient to sow a good plot of ground in the grass garden were saved, and in 1899 an excellent stand was secured that grew and developed vigorously and held its own remarkably well during the long dry spells of 1899 and 1900.

Gama Grass (*Tripsacum dactyloides*).

The writer, while making a field inspection of the central Texas ranges, looking up their native grasses and forage plants, discovered a few bunches only of a stout, coarse, branching perennial, and was much impressed with the idea of its probable value for pasture purposes. It was growing in large bunches from masses of stout roots, the stems and their broad leaves being numerous and from 4 to 6 feet high. During the year 1898 the bunches found growing in a low, rich, moist valley were watched with the view to securing seeds for tests in the grass garden. Abundant seed heads formed, but none of the seeds matured before the frosty autumn weather came on. Again, in 1899, the seed development was watched, and some seeds gathered, but, as in the year before, they were not matured. These facts seemed to demonstrate that the gama grass could not be propagated through seed grown in the section, and steps were taken to propagate it by use of the roots. A few of the large roots were dug up, cut into small bits, and planted in drills in the grass garden. This was in the autumn of 1899. Again, in the spring of 1900, other small roots were planted. In each case the root development was surprisingly great and quick. By the beginning of the autumn of 1900 the roots had largely multiplied and the stems were from 3 to 5 feet high. One planting was made on a rocky hillside, the other in low, flat, rich ground. The growth in the valley was more vigorous than that on the higher land, but the latter was strong and vigorous. The suggestion is made that central Texas stockmen and farmers can use this grass to excellent advantage in their efforts to improve their lowland pastures. From early spring till late in the autumn the leaves continue green. The stems are coarse and harsh, and the gama grass hay is not nearly as satisfactory as that of many other native grasses. The roots, however, penetrate deeply into the ground, and being very close, compact, and tough, the grass will stand much dry weather and rough pasturing.

Grama Grasses.

For pasture purposes throughout central Texas curly mesquite is believed to be entitled to the first rank. Next follow, in the order named, buffalo grass and needle grass, and then come the three gramas that are native to the section. As to their relative merits it is not easy to decide. In the matter of quantity in central Texas blue grama and side oats grama are more abundant over a larger area than the black grama.

Black Grama (*Hilaria mutica*).

As far back as early in the eighties the Iatan Valley in Mitchell County was covered with a heavy growth of this grass. The stiff red soil seemed to be peculiarly favorable to its growth. All that section was an open range, and free grass was the rule. Every year large quantities of this grass were cut and baled, and the hay was regarded as being excellent, though somewhat harsh. Since then the writer has found the same grass growing in other counties of central Texas, and quite as vigorously in the black-land valleys as in the red lands. In the immediate neighborhood of the grass station C. W. Merchant has two pastures kept as winter range for his white-faced thoroughbred cattle. The soil is a rather loose brown loam with a clay subsoil. The principal grass is the black grama, which grows abundantly and vigorously. A public road on the west side of one of these pastures separates it from the Parramore pasture, in which the surface soil is sandy. In this sandy land the black grama does not grow at all vigorously. Stockmen of the section agree in their statements that it will not grow well except in the heavier clay soils. At all events, the writer does not now recall a single pasture in all of central Texas in which it is growing to any decided extent, except where the soils are heavy, either red or black clay. Seeds were drilled and broadcasted in 1899 and again in 1900 in the grass garden, both in heavy and lighter soils. In each case a good stand was secured, but the best results were obtained from the plantings in the heavy soil. In central Texas this grass withstands the drought and bears pasturing very well. It grows tall enough for hay purposes, but as there are several better hay grasses that grow quite as well in the section, it is not recommended for hay. It is recommended, however, for pasture purposes. It is specially valuable for winter grazing, as the stems remain green long after the leaves have become brown, and to all appearances dead. As it is a perennial and seeds abundantly whenever there is rain in the early part of the year, it is valuable for the purpose of renovating worn-out or tramped-out native pastures.

BLUE GRAMA (*Bouteloua oligostachya*).

In every county in central Texas blue grama is to be found a native in the pastures, and yet it is not nearly so common as the stockmen would like to have it. There are two very closely related species, the other being known to agrostologists as *Bouteloua hirsuta*, the seed heads of which are darker than the former, really the only difference noticeable to the unscientific observer. Considering them as being practically the same, it may be said of them that they are not specially valuable as hay grasses. Though their stems are often tall enough to be cut, the leafage is neither heavy enough nor, as a rule, long enough for hay purposes. They grow well on the high arid plains and bench lands, and also in the lower and damper pasture lands. The blue grama is often confused in the minds of stockmen and farmers with buffalo grass, from which it differs in several important respects.

Side Oats Grama (*Bouteloua curtipendula*).

This is justly regarded by the well informed as one of the best of the native grasses of central Texas. It grows equally well in the uplands and lowlands, in pastures and in fallow lands. It produces a great many seeds that do not shatter badly, grows tall enough to be cut, and makes much fodder, which when cured is soft and much relished by stock, and it may be fairly classed with the recommended hay grasses. Its special value, however, is for grazing or pasture. It is a perennial, and is easily propagated from the seeds. Several tests were made of this variety in the grass garden. Some seeds were gathered on the range in the autumn of 1898 and were sown April 18, 1899. An excellent stand was secured, and the grass stood the drought of 1899 satisfactorily, and in 1900 made a splendid showing. In the spring of 1900 some seeds grown in the State of Washington and received from the Agrostologist were broadcasted on a high, rather dry level in the grass garden. A very good stand was secured, the grass grew vigorously, seeded well, and altogether gave satisfactory results. The same grass is known as "tall grama" and as "prairie oats" in some sections, in and out of Texas, but everywhere it is regarded as a valuable grass.

Johnson Grass (*Andropogon halepensis*).

If Johnson grass happens to be mentioned in any crowd of stockmen and farmers in Texas, it is safe to conclude in advance that there will be much disputing in regard to it. There are farmers in central Texas, known to be successful, practical, sensible men, who insist that it is a very valuable grass and does not deserve the great amount of abuse heaped on it. On the other hand, many who are equally as favorably known declare it to be an unmitigated nuisance. Among stockmen there is about as much difference of opinion. Those who do no regular farming, but confine their farming operations to growing stock feed, say it is the very best all-around stuff they can grow. On the other hand, of those who are farmers as well as stockmen, many are pronounced in their opposition to it. None of the seeds were sown in the grass garden, but in the farms in the neighborhood are many fields seeded to it. Under ordinary circumstances it is a vigorous grass, growing 3 to 5 and often 6 feet high in the rich, moist valley land. Because of its rapid growth it frequently gives two to four cuttings yearly, the yield being from 3 to 5 and sometimes as much as 7 to 8 tons of hay, which, if cut when in full bloom, is rich, soft, and much relished by stock. Johnson grass is not recommended for cultivation by farmers, and is only recommended to stockmen who do not care to do farming further than to grow such stuffs as will make good rough stock feed.

KNOT GRASS (*Paspalum distichum*).

There is no difference of opinion among either the stockmen or the farmers of Texas as to this grass. All agree that it is one of the most valuable of all the native grasses of the section. It is to be found in low, moist soils throughout central Texas. Under suitable conditions its runners will often grow out from the roots 20 to 30 or more feet, and as they take root en route a single plant will furnish a large quantity of rich feed. It has a creeping habit of growth which rarely admits of its being cut for hay purposes. Several tests were made in the grass garden during the years 1898, 1899, and 1900. The seeds gathered in the neighborhood were sown in drills and broadcast in low, moist soils, and no difficulty was experienced in getting excellent stands. The roots were vigorous from the start and good growths of stems were secured, which rapidly covered the ground to considerable distances on every side. The habit of growth is similar to that of Bermuda grass, but knot grass is coarser, and in central Texas is the stronger grower of the two, and stands long periods of hot and dry weather very much better. No native grass of the section stands more rough treatment. On a farm not far from the station it was noticed by the writer that the horses and cattle in a pasture where it was growing in several low places kept it eaten down as close to the roots as possible, and yet the roots were strong and healthy. It can be propagated readily by sowing the seeds or by planting the roots, and would be very useful to cover naked spots in lowland pastures. It is a perennial and its local name is "eternity grass."

LITTLE BLUE STEM (*Andropogon scoparius* and *Adropogon torreyanus*).

These are two varieties of grass growing as natives throughout central Texas, each known locally as little blue-stem. The habit of growth is similar in the matter of roots, stems, and leaves, but the blooms and seed heads of the latter are more feathery; hence its other common name—feather edge or feather blue stem. The former seems to prefer the low lands, but is often to be found in the higher levels. The latter is a common grass on the high and dry prairies. It grows 2 to 3 and sometimes 4 feet high, in bunches, and in the early autumn matures an abundance of seed. When cut and cured it makes a soft hay, which cattle eat with relish. Tests made in the station garden showed that it is easily propagated from the seed. Under favorable conditions the roots spread and develop a fair sod. Both for pasture and hay purposes it is well worth the attention of central Texas stockmen and farmers.

THE MILLETS.

There are two of the wild millets growing pretty well throughout central Texas. Arizona millet (*Chætochloa macrostachya*) is to be found in every neighborhood, largely on the open prairies. "Wild millet" is to be found principally in the cultivated fields, and is regarded as being a very troublesome weed. Both grow so well as to suggest that the soil and climatic conditions of the section are especially favorable to millets generally. They grow to a height of 18 to 30 inches, mature abundant crops of seed, produce much fodder, and make a light but very fair hay. A lot of the wild millet was baled on the station grounds in 1899 and 1900, and the bales, when opened after several months, were found to be in excellent condition. Encouraged by the success following the handling of these two wild varieties, several varieties of the "tame" millets were quite thoroughly tested. Seeds of German millet (*Chætochloa germanica*) were purchased in the open market and plantings were made in 1899 and in 1900. Hungarian millet was also carefully tested, as were the Japanese barnyard millet (*Panicum crus-galli*), a variety known as Shama millet (*Panicum frumentacum*), pearl millet (*Pennisetum spicatum*), and a variety of broom-corn millet (*Panicum milaceum*). Without going into particulars as to the results of these several tests, it may be stated generally that all of them were found to be well worth the attention of central Texas stockmen and farmers. The Hungarian did not grow so tall as the others, but quite high enough to be cut. March 15, 1899, seed of the Japanese barnyard millet were sown in thin land, on a hillside, and yielded heavily. In the efforts made to cure it it was found that it molded easily and had to be handled very carefully. Splendid stands of the Shama millet were secured from plantings of March 17 and April 10, 1899, and most excellent results were secured. No difficulty was experienced in the efforts made to cure it, and the hay that was baled was quite equal to the best hay grown in or imported into the section. Pearl millet seed sown April 18, 1899, turned out finely. The stalks grew to be 6 to 7 feet tall, with heads 8 to 10 inches long, which matured well. There was much fodder and the hay made from this millet was baled and fed to the stock, which ate it with relish. The broom-corn millet seed sown in April, 1900, gave most satisfactory results. The yield was large and the seed matured before July. There is no reason why central Texas stockmen and farmers, in years of ordinary seasons, should fail to have abundant supplies of hay for their live stock. They can hardly make a mistake in selecting any of the millets mentioned. If called on to recommend any one of them in preference to the others, the writer would find it difficult to decide between them. The tests made in the grass garden were in drills and also broadcast, but very little, if any, difference in the results was noticeable. For a crop of grain for seed purposes, perhaps drilling gives the better results.

NEEDLE GRASS (*Aristida fasciculata*).

As a winter and early spring grass, nothing on the central Texas ranges will take the place of this grass. To those who do not know it it appears to be very much of a nuisance. The ripe seeds are sharp and sometimes pierce the tongues of cattle, and become fastened in the wool of sheep. As a rule cattle do not eat it when the seeds are ripe, especially when there is other grass, but after the needles fall they feed on the stems and leaves. Mixed with curly mesquite and buffalo grass in quantities and with fair proportions of the several varieties of the grama grasses, it helps to make a pasture which is all that reasonable stockmen and farmers could desire. It is among the first of the native pasture grasses to green out in the early spring, and all through an average winter in the section green shoots are to be found about the roots, which are protected by the cured stems that cling thereto. Its drought-resisting qualities are greater than almost any other native pasture grass. No other grass spreads so rapidly when given a chance to mature its seed. It is safe to say that it is about the earliest of all the pasture grasses, is as fattening as the best, is more generally distributed than any other, and more readily reseeds itself than the others, and hence contributes more than any other to the annual renewal of the range. The more of it there is on a central Texas cow ranch the more valuable the range. No special tests were deemed necessary to determine its general value, but roots were taken up and transplanted to determine whether it could be used to advantage in covering naked spots in pastures. The bunches so planted grew and developed satisfactorily. In order to determine how far it could be utilized in efforts to renew ranges, furrows were plowed from east to west across about 10 acres of station pasture land. This was done in early spring, when the seeds of the needle grass had matured and fallen to the ground. The prevailing south winds blew them by millions into and across these furrows, where they were caught by the soft plowed soil, and the following spring the furrows were well seeded to this grass. Elsewhere in this report the particulars of this experiment are given.

Rescue Grass (*Bromus unioloides*).

This is not a native grass of central Texas. Not until 1898 was it noticed by the writer in this section. Then he found it only in the court-house yard in Sweetwater, Nolan County, and along the reservation of the Texas and Pacific Railroad, which extends east to west across several central Texas counties. Stockmen in several counties stated that they had seen it occasionally in their sections, and in some neighborhoods it was reported in quantities sufficient to constitute a rather important factor in the make-up of the ranges. In 1899, and again in 1900, a few bunches were noticed in different parts of Taylor County, away from the railroad, and it is very probable that it will soon spread over that and the adjoining counties. It is believed that the first introduction was due to the seed falling from the moving freight cars in which rescue-grass hay was being shipped. Some Oregon-grown seed received from the Agrostologist was sown in the grass garden May 4, 1899. An excellent stand was secured, but when the stalks were only 6 to 8 inches tall the seed heads began to form. At no time was the growth vigorous, and by October 1 the leaves were all dead, and the roots, though they survived the drought of that year, did not revive after the autumn rains began. Some seeds of the volunteer growth on the Texas and Pacific Railroad reservation were gathered in 1899 and were sown in the grass garden in the spring of 1900, but following the sowing late in May there was a dry spell and very few, if any, of them germinated, whether because of the dry weather or because the seeds were not fully matured when gathered was not determined. As no satisfactory tests of this grass were made in the course of the station work, and the only conclusions practicable are based on observations as to the volunteer growth referred to, no definite recommendation as to the grass for central Texas is ventured. It is the belief of the writer, however, that if well-matured seed be planted anywhere in the section, under normal conditions, rescue grass will prove a very valuable addition to the many excellent grasses, native and imported, known to do well in the section. Reports from other sections in and out of Texas show it to be a superior grass both for hay and pasture purposes. (See fig. 4.)

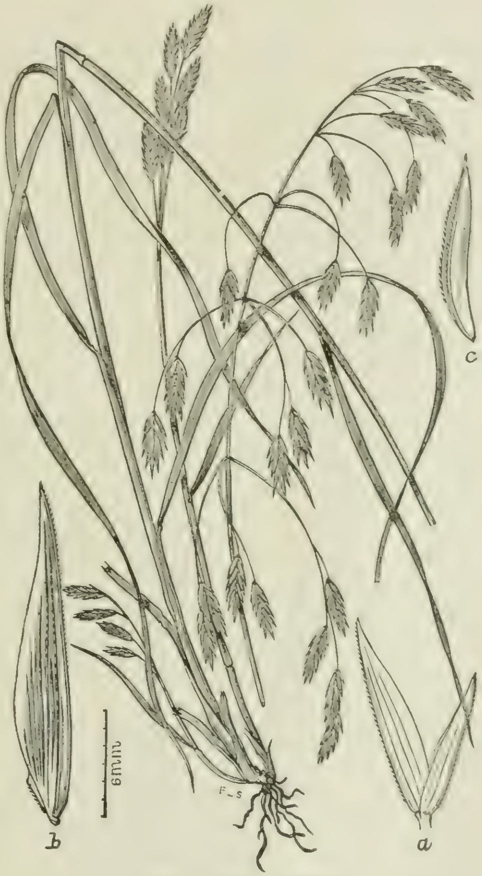


FIG. 4.—Rescue grass.

THE SEDGES (*Cyperus* and *Carex* spp.).

These are not, in fact, true grasses, but as they are distributed over a wide extent of country, including Central Texas, and in the early spring furnish an abundant supply of fairly good green forage, they have a recognized value among stockmen.

Smooth Brome Grass (*Bromus inermis*).

So much had been said officially and unofficially in favor of this grass that very earnest efforts were made in the grass garden in 1898, 1899, and 1900 to determine its adaptability to the climatic and soil conditions of central Texas. Seeds received from the Agrostologist were sown October 4 and November 15, 1898, and April 10, 1899. Those sown in the autumn germinated, but the grass did not survive the freezes of the following February. Those sown in April also germinated, a fair stand of grass was secured, and it lived through the hot and dry weather of July and August; but early in September it gave way, and the roots though alive did not revive after the autumn rains began. In the fall of 1899 a sowing was made early in November, but the rainfall in that month was only 0.24 inch, in December only 0.30 inch, and in January, 1901, only 0.03 inch, and practically no seeds put in the ground after October, 1900, germinated. It is said to withstand the severest drought and cold, and is highly recommended as an excellent pasture grass and as a second quality hay grass. The tests made as above at the grass and forage plant station did not give such results as justify recommending it for any purpose to central Texas stockmen and farmers. The probabilities are that under normal conditions it will do well in the section, and tests on a small scale may be made.

The Sorghums.

Under this general head mention will be made of several tests made at the grass station. In addition to the varieties well known all over Texas, three not so well known were tested with gratifying results, namely, Jerusalem corn, Kafir corn, and milo maize. Plantings of seed of Jerusalem corn were made in April, May, and June, 1899, in low, moist land, on a gravelly hillside, and on higher, level, dry land. The seeds were sown in drills from east to west, beginning in the valley and ending on top of a rather rough hill. Excellent stands were secured, and the rainfall being good, the plants grew vigorously until about August 1. During August the precipitation was only 0.10 inch, only 0.44 inch during September, and nothing during October till about the 16th, when the precipitation was 0.01 inch. On October 26 the first rainfall of any consequence (2.09 inches) since June 30 occurred. During all these dry weeks the weather was extremely hot, with hot winds blowing nearly all day. That any of the forage plants revived is remarkable. The Jerusalem corn lived through the drought, and by November 1 had apparently taken a new lease on life, and continued to grow until a fair crop of seeds matured.

Kafir corn and milo maize have been grown in many neighborhoods through central Texas during the past six or seven years, and no tests were deemed necessary as part of the station work to determine their value as stock feed, but tests were made with the special view to determining whether the cured products could be baled successfully and advantageously. Seeds of both, some of them gotten from the Agrostologist and others in the open market, were sown in the grass garden in 1899 at the same dates the seeds of Jerusalem corn were sown. Some of the drills of each, where the stalks stood close together, were cut, cured, and baled. No difficulty was experienced in the efforts to cure them in shocks, but it was not practicable to make the bales very compact; hence the hay dried out considerably. The varieties of Kafir corn grown in the grass garden were the red and the black-hulled white. The former was a little in advance of the latter in maturing seeds, but the difference was trifling. Varieties of the sorghums mentioned above may be planted from April to July in central Texas, and under normal conditions will give two to three cuttings, and mature seeds during September.

Of the several varieties of the saccharine sorghums tested in the grass garden all were found to be fairly well adapted to the climatic and soil conditions of that section. No very material differences were noticeable in them. The tests were not made except to determine whether sorghum hay could be baled to advantage and be given a commercial value by putting it in convenient shape for shipping. The amber and orange are about the only varieties grown in central Texas, the former being somewhat earlier, the latter being regarded as about the best all-around cane.

In this connection it may be well to state that in the immediate vicinity of the grass garden several rows of corn were planted to determine the drought-resisting qualities of corn as compared with sorghum. The results of that test were very definite. The sorghums not only lived through the drought mentioned, but matured seeds satisfactorily. The corn, on the other hand, gave way under the influence of the hot winds and scant moisture and never revived. As to the value of the sorghums for forage purposes nothing need be stated in this connection beyond the general conclusions that they give more and better fodder than corn, and their matured seeds are very nearly as valuable as corn for purposes of sustaining and fattening stock.

TEXAS BLUE GRASS (*Poa arachnifera*).

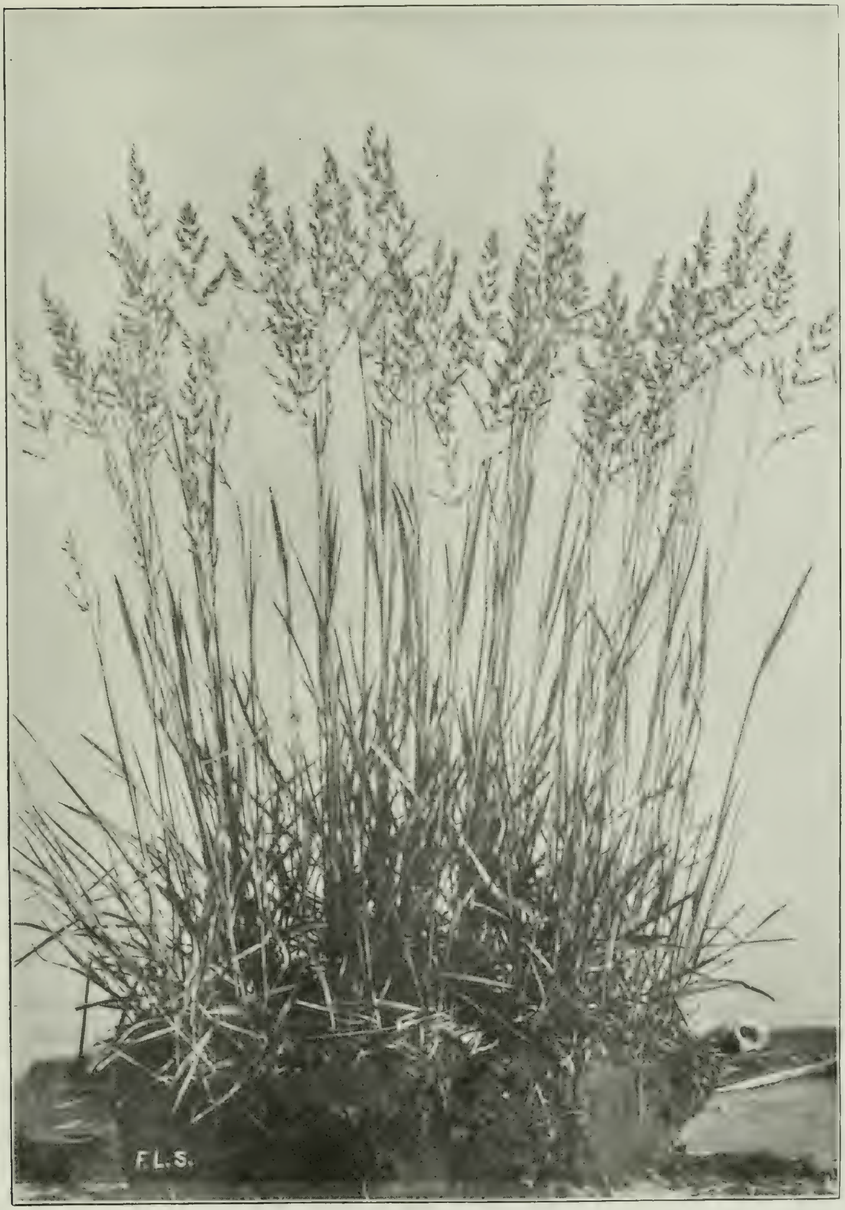
This has been a well known and highly valued grass during many years past in many counties east and south of central Texas, but only during the past two or three years has it made its appearance as far north and west as Taylor County. In 1900 it was noticed by the writer growing in spots in several places in the county, and specimens taken from the range were sent to him from Callahan, Jones, and Shackelford counties. In the spring of 1898 Prof. Jared G. Smith, of the Division of Agrostology, secured roots and seeds from Collins County and northern Texas and planted them in one of the station pastures. But the roots soon died under the influence of the long, hot, and dry summer of that year, and none of the seeds germinated. In the spring of 1899 seeds were broadcasted in the grass garden, on a small square of low, moist land. There was practically no rain thereafter for several weeks, and only a few seeds germinated and none of them lived. Again, in 1900, some seeds were sown in drills in the garden, but nothing like a good stand was secured, and the roots that lived into the summer were never vigorous. It is officially reported to be a winter-growing grass, and from November to May furnishes an abundance of luxuriant pasturage in sections such as northern Texas, suited to its best development. The tests made with it in connection with the station work were disappointing. It can be propagated satisfactorily by means of its roots, which may be divided into bits and planted 12 to 18 inches apart in moist fallow lands. It may be well for central Texas stockmen and farmers to use the roots for improving their winter pastures. (See Pl. I.)

WHITE TOP GRASS (*Triodia albescens*).

This is an excellent hay grass for central Texas. It is to be found pretty generally throughout the section, principally in the lowlands, where it grows from 18 to 20 inches high and produces an abundance of soft stems and leaves. No special tests were made with it in the grass garden, as it is well known and needs no special commendation. It is easily propagated from the seeds, which may be gathered in the early autumn. It would pay those interested to cultivate it for hay purposes.

WILD RYE (*Elymus canadensis*).

This is by far the most valuable of all the first-class native hay grasses of central Texas, and since it is also a splendid pasture grass, it is only fair to say that it deserves the highest consideration at the hands of stockmen and farmers. In all the valley-land section it is found growing in rich soil near streams, but it will grow and do well on the higher levels. The writer's attention was first attracted to it by the fact that in the early part of June, 1899, when no other range grasses of the section had begun to green out, he found it 4 to 5 inches high in the valley of Indian Creek, in Taylor County. By arrangement with Mr. P. O. Forbus, on whose place the grass was growing, about an acre was cleared of brush and the former year's weeds, and the surface of the ground was broken with an iron-tooth harrow. By the opening of spring a splendid stand of this grass had been secured two to three weeks in advance of others in the neighborhood. By June 5



TEXAS BLUE GRASS, FROM PHOTOGRAPH OF SOD GROWN AT WASHINGTON, D. C.

it was high enough to be mowed, and a heavy crop of hay was secured. By July 3 a second crop was secured, the bundles measuring from 20 to 30 inches in length. A long, dry spell of very hot weather followed this second cutting, but the grass continued comparatively green and growing through it all, while the upland grass and the other valley grasses suffered very much. In November a third crop of hay was cut, which averaged about 15 inches in length. In the spring of 1900 the same spot was again cultivated with the iron-tooth harrow, together with about 2 acres more in the valley. Growing during the early spring and summer side by side with a splendid field of wheat on rich fallow land, the native perennial growth of wild rye held its own, standing very nearly if not quite as thick on the ground as the wheat, and growing much taller. Two crops of excellent hay were secured, the first after the seeds were fully formed, the second just before the second growth of seeds appeared. The grass was ricked, readily cured, and baled, and no hay grown in or imported into central Texas looked better, or in fact was better, than the wild-rye hay. A bale of the seeded hay and one that was not seeded were sent to the Division of Agrostology, Washington City, where it was pronounced to be of superior quality. Stock are exceptionally fond of the green grass as well as the hay. It is about the earliest pasture grass of central Texas, and may be relied on to continue green as far, if not farther, into the winter months than any of the native grasses of the section.

Wild Timothy (*Muhlenbergia racemosa*).

This is not, in fact, a timothy grass, but in general appearance resembles it, and is known locally as wild timothy. It was found growing on Indian Creek, in Taylor County, in quantities, and later was found, a bunch here and there, in several other sections of central Texas, always in low, moist soils, and always vigorous looking. It grew 38 to 54 inches high and produced seeds and fodder abundantly. Seeds gathered in 1899 and sown in the grass garden gave satisfactory results. Enough of the grass as found growing on Indian Creek was cut and cured to make a fair-sized bale. This was opened and examined several months later (during February, 1901) and was found to be in good condition—quite equal to any of the baled grasses imported into central Texas. Farmers in Taylor and Eastland counties who know it well state that their stock prefer this grass to most of the others growing on their places. An acre of fairly rich moist land seeded down to wild timothy ought to produce, in a fair season, 2 to 3 tons of the best quality of hay.

Other Central Texas Grasses.

In a general way it may be stated that throughout central Texas the variety of native grasses of substantial value is large, and if stockmen and farmers of the section realized the possibilities of their ranges and meadows they would place higher money values on their properties. In a 400-acre winter pasture in Mitchell County, owned by Mr. B. Van Tuyl, the writer pointed out to the owner 56 different grasses and forage plants, all natives. In addition to the native grasses above enumerated, others well worth the consideration of central Texas stockmen and farmers might be noted, but it is believed that a sufficient number have been mentioned to demonstrate to those most interested the very great possibilities of the section for live-stock purposes.

It may be well also to mention that while a fair proportion of the grasses not natives tested in the grass garden were found to be valuable for the section, and well worth the consideration of stockmen and farmers, a large number were found to be entirely unsuited to its climate and soil conditions.

Legumes in Central Texas.

Among the most interesting of the experiments made in the grass garden were those with several varieties of alfalfa, beggarweeds, butterfly pea, the clovers, the cowpeas, the Canada field pea, gram or chick pea, the Metcalfe bean, soy bean, sulla, sanfoin, Texas pea, velvet bean, the vetches, and a native wild bean that specially attracted the attention of the writer. These experiments clearly demonstrated that the climate and soils of central Texas are favorable to the growth and best development of a larger number of the legumes than had previously been supposed. The following notes cover the most important tests.

Alfalfa or Lucern (*Medicago sativa*).

During the several years immediately preceding the establishment of the grass and forage station (in 1898) farmers of central Texas experimented with the common alfalfa. The writer visited several farms in the section where tests had been and were being made, but as they were on irrigated farms and the station work was instituted and conducted distinctly to determine what grasses and forage plants could be grown successfully in the section without irrigation, no further mention of them need be made here. Special mention will be made, however, in this connection of tests made near Merkel, in Taylor County, Tex., by Major Garote, a retired United States Army officer, who is devoting much attention to developing the resources of the section as a grass and fruit country. About 1895 he sowed lucern in sandy land, and had no difficulty in securing a good stand. The growth was satisfactory, but was kept eaten down by rabbits, which swarmed into his alfalfa patch. After trying during two years to grow the crop faster than the rabbits could eat it down, he abandoned the project and plowed up the roots, except those near a fence row, and he left those undisturbed only because he could not get at them conveniently with the plow. In 1898 the roots left developed astonishingly, and in 1899 the stalks were too large and too tough to suffer seriously on account of the rabbits. In 1900, when the writer visited the Garote farm, he found the alfalfa growing as vigorously as any one could reasonably wish without any cultivation at all. Bunches, each one of which would have furnished a good sized bundle, were examined, some of them 24 to 36 inches high, and the stalks were well leaved and full of blossoms and seeds. In March, 1898, Prof. Jared G. Smith sowed a plot of the station grass garden with lucern on freshly broken sod. A rather thin stand was secured, and the drought of that year was very hard on it. In the autumn following the roots that survived began a vigorous growth, but the most of them were destroyed by prairie dogs and rabbits, which congregated on the alfalfa plot from far and near. In October, 1898, the plot was plowed deep and a surprising number of roots were found still alive. The following spring (1899) they made a vigorous growth, and a small plot (about 25 by 25 feet) on which there was a satisfactory stand was set apart for further tests. In the meantime the garden had been fenced in with woven wire and the prairie dogs and rabbits shut out. By June the stalks were 18 to 27 inches high, and a first cutting was made; July 2 a second cutting was made, many of the stalks measuring 24 to 28 inches; July 22 a third crop was ready for cutting, some of the stems measuring 18 to 20 inches in length. From November 1 to July there was abundant rainfall for the section and season. The alfalfa on this spot made a splendid growth in 1899 and in 1900, and in March, 1901, when the station was turned over to its owner, there were roots growing from 3 to 5 feet down into the heavy soil nearly as strong and vigorous apparently as in the Garote farm of lighter sandy soil. In 1899 (April 25) alfalfa seeds were sown in the garden in drills. Good stands were secured, and the growth was satisfactory up to about June 20, by which time there was a severe drought. By August 1 the foliage was dried up, and even the roots appeared to be dead or dying. October 26 a good rain fell, and in a few days green leaves had started from the roots, and by the beginning of winter (December 1) the new growth was 8 to 10 inches high. During November there were several frosts, but the alfalfa continued green through the winter.

TURKESTAN ALFALFA (*Medicago sativa* var. *turkestanica*).

In April, 1899, seeds of alfalfa from Bokhara, Tashkend, and Samarkand—all in Russian Turkestan—were sown in the grass garden in drills. About the same time seeds of the common lucern were also sown in the garden. The Turkestan variety came up quite as well as the other, and quite as good a stand was secured. The drought of that year was protracted and very severe, and both varieties suffered greatly—the common lucern more than the other. By August the plants began to fail, and by September the roots looked to be dead or dying. Immediately following the October rains noted above the roots revived, and by the middle of November a vigorous growth of new foliage had been made, and continued green through the winter.

Oasis Alfalfa.

Three plantings of seeds of Oasis alfalfa from Tunis were made in the grass garden during 1899. The first, in February, did not give good results. On account of several frosts the seeds failed to germinate. In April seeds were sown in two plots, one in low and rather damp soil, the other on higher and dryer land. Excellent stands were secured and the growth was vigorous from the start. By July 30 the drought was on and the plants were looking wilted. By August 1 the leaves had fallen off and the roots appeared to be dead. Immediately following rain on October 26, the roots began to put out new foliage, which by November 15 was 8 to 12 inches tall. By December, in spite of the frosts of November, the plot was green, and continued so during the winter. The following spring (1900) both plots developed satisfactorily in spite of the long dry and hot spell of that year, stood up well, and went through the autumn and winter in good shape. In March, 1901, when the station was turned over to the owner, this variety was looking more vigorous than either of the others.

As the result of these several experiments with alfalfa it appears reasonably certain (1) that all the varieties named can be grown successfully without irrigation in central Texas; (2) that during seasons when the rainfall is abundant the common alfalfa or lucern will do better than the Turkestan varieties, and they rather better than the oasis alfalfa; (3) that during the long dry spells that are frequently to be expected throughout the section the oasis alfalfa will hold its own better than the Turkestan varieties, and they better than the common lucern; (4) that sandy soils are better for lucern than the heavier soils, as they hold moisture longer.

Florida Beggarweed (*Desmodium tortuosum*).

Seeds of this plant were secured direct from Florida and sown in the grass garden. An excellent stand was secured. The plants grew vigorously, and notwithstanding the ground was upland, very rocky, and very thin, the growth was larger than desired; that is to say, the plants developed into bushes from 4 to 6 feet tall, the stems being woody and altogether too coarse for hay purposes. As the leaves shed easily, unless the plants are grown very thick on the ground to insure the stems being small, it will not be practicable to bale the hay. If grown so that it can be baled to advantage, a great abundance of superior feed for stock can be grown on a few acres, as the foliage and seeds are rich in the best hay properties. As a renovator of worn-out soils or as a green manure nothing better can be recommended. Stockmen and farmers will do well to familiarize themselves with the beggarweed. It is confidently believed that in years of normal rainfall in central Texas 8 to 10 tons can be grown to the acre on rich valley lands. In the southern States large crops of it are grown after crops of oats are harvested. For ensilage purposes it is known to have a very definite value.

THE CLOVERS.

Outside of the grass and forage plant station very few efforts have been made in central Texas to grow any of the clovers, and yet it is a fact that some of them can be grown to advantage. During 1898 seeds of several varieties were sown in the grass garden. Prairie clover (*Kuhnistera*), common throughout the prairie region, produces on the range a fair amount of very good forage, which is relished by stock. It is not believed that it would pay to cultivate it.

ALSIKE CLOVER (*Trifolium hybridum*).

In 1900 (March 10) several rows of this clover were planted in the grass garden. A very good stand was secured and the plants grew nicely. During the hot and dry month of June they suffered very much, but revived after the normal rainfall during July. In August they again had a wilted look, but the roots survived, and by September 5 were growing again. During September the rainfall was exceptionally large (9.65 inches) and by October the plants had made a satisfactory growth. October was a seasonable month and the development was good. There was but little rainfall during November, December, and January (1901) (0.24, 0.30, and 0.03 inch, respectively). During February, 1901, the precipitation was only 1.44 inches. The shortage was rather serious during March, being only 0.72 inch. During November there was considerable frost. In December, January, and February, there was decided winter—frequent killing frosts. March was also a cold month. These conditions were hard on the plants, which had not had a fair chance to form strong roots. Early in December they began to fail, and by March were to all appearances badly damaged. However, when the station lease expired (March 19) and the station was given up to the owner practically every root of the alsike clover had begun to put out new shoots.

BUR CLOVER (*Medicago maculata, Medicago denticulata*).

In 1898 the writer found the variety first mentioned growing in Mitchell County near Colorado City. In all probability the seeds were brought from California in the wool of sheep which had been shipped into the county from that State in large numbers from 1883 to 1887. It was growing vigorously, but not in quantities sufficient to make it anything of a factor in the matter of forage supply. In the spring of 1899 seeds of the latter variety were sown in the grass garden. Only a few germinated, hence only a few bunches were secured. They grew well and remained green till August. The drought of that year destroyed most of the roots. In December those that survived greened out nicely and went into the spring of 1900 in good shape. The runners grew to be 3½ to 4 feet long and the leafage was exceptionally good. In the spring of 1900 other seeds were sown, but in a rather cloddy soil, and none of them germinated. Here lies the only serious difficulty in the matter of growing bur clover in central Texas—it is very difficult to secure good stands. Nothing tested in the grass garden showed better drought-resisting qualities, and it is believed that a good stand once secured (which is quite possible, though difficult) will yield satisfactory results. It is liable, however, to be winterkilled, and to this extent is not regarded as a very certain forage crop. The writer studied the bur clover in California pastures, and as the result of his observations and personal experiences with it can recommend that it be further tested in central Texas. It is believed that the best time for sowing the seeds in this section is in the autumn months, say during October and as late as November.

MAMMOTH CLOVER (*Trifolium medium*).

It was believed that this variety, known also as sapling clover, would do better in central Texas than the common red clover, which it much resembles, as its habit of growth is more vigorous as a rule. A few seeds were sown broadcast in the grass garden in 1899, but an indifferent stand was secured and the few plants were much crowded and injured by weeds, and most of them were killed in the efforts to destroy the weeds. The growth was never vigorous, and when the drought came on every plant died. March 20 a plot of the grass garden was planted with seeds of this variety, in drills. A good stand was secured which was afterwards reduced by cutworms. The plants left went through the summer very well, but many of the roots were winterkilled. Those that survived greened out in the spring of 1901, and on March 19 were growing and developing satisfactorily. As this single test of the variety was very inconclusive in results, the only suggestion ventured is that further tests should be made, the probability being that it will be found to be fairly well adapted to local conditions.

RED CLOVER (*Trifolium pratense*).

The efforts made to grow red clover in the grass garden were mostly failures. In April, 1899, two plantings were made, broadcast, one in low and moist, the other in higher and drier, soil. Excellent stands were secured and the plants grew vigorously and promised satisfactory results. The weed growth of the season was heavy and many of the clover roots were choked. Early in May, in spite of this difficulty, the plants were 8 to 16 inches high and continued green through June and until late in July. The latter part of July and the early days of August were exceptionally hot, even for this section. By September very few of the roots were alive, and none of them survived the winter.

January 19, 1901, seeds of red clover were drilled in the grass garden with wheat, on the presumption that as a nurse crop the wheat would protect the young roots through the winter and spring and enable them to enter the summer with a strong root development. Only a few of the seeds germinated, however, and they were never vigorous. A few seeds were drilled in the garden March 20, 1900. They germinated very satisfactorily, but the plants were never very strong. They survived during the hot and dry summer months, but most of them were winterkilled.

RUSSIAN RED CLOVER (*Trifolium pratense* var. *pallida*).

Only one test was made of this variety in the grass garden. March 20 seeds were drilled, a good stand was secured, and the plants grew well. They went through the hot and dry months fairly well and made a satisfactory growth, but many of them were winterkilled. March 19 the roots had greened out well. Altogether, the variety seems better adapted to local conditions than the common red clover, but the results of the tests do not justify more than a general suggestion that it should be given further tests, with the probabilities in favor of good results.

SWEET CLOVER (*Melilotus alba*).

Of all the clovers tested in the course of the station work near Abilene, none gave nearly such satisfactory results as this variety. Only one test was made, and that under conditions far from favorable, yet the results were eminently satisfactory. Seeds were drilled in low, rather moist, fertile soil, March 18, and apparently every seed germinated quickly. The stand secured was all that could have been wished for. From the start the plants grew vigorously and were soon quite 2 feet high on an average, and a fair crop of seeds was matured. In one row, near the banks of the water hole in which water stood the greater part of the spring and into the early summer, the growth was very strong. Many of the plants measured 3½ to 4 feet high. The leafage of all the plants in the garden was heavy and a fair crop of seeds was matured. During the hot and dry weather of June, July, and August the plants suffered, many of the leaves falling off. The month of September was hot, but the rainfall was exceptionally heavy, and under such influences the sweet clover revived and went into the winter in vigorous condition. It suffered little, if any, on account of the frosts of December, 1900, and January and February, 1901. March, 1901, was a cold month for central Texas, but every root of the sweet clover on March 19, when the station work closed, was alive and vigorous. No effort was made to convert the green growth into hay. Had the plants been cut when young and tender, doubtless a good quality of fairly soft hay could have been secured. The cutting, however, was done when they were 2 to 3 feet high and the stems were woody. A couple of bales of the hay were made, one of which was given to Mr. P. O. Forbus (foreman of the station working force), who placed it in his own barn, where it perfumed his entire hay crop. The other bale, made in the summer of 1900, was opened in April, 1901, and fed to a horse and a cow. The horse ate a part of it, without much relish, but the cow greedily ate the balance. Several tests have been made of the sweet clover in the Abilene country, in every case with satisfactory results. Mr. F. C. Digby-Roberts, now mayor of Abilene, saved it for his honeybees, and was much pleased with the results. Others tested it as a green forage crop. They found that cattle and horses did not relish it much at first, but as it was green before anything else on the range, they soon took kindly to it and ate it readily. Some roots of this clover dug up in the grass garden and sent to the Division of Agrostology, Washington, D. C., were surprisingly long and large. It is deemed safe to recommend sweet clover for green forage and hay purposes to central Texas stockmen and farmers.

WHITE CLOVER (*Trifolium repens*).

The tests made in the grass garden with this variety were not satisfactory. Seeds were sown broadcast in the spring of 1899, and a thin stand only was secured. At no time were the plants vigorous. During the summer most of the roots died, and those that survived were winterkilled. November 13, 1900, seeds were drilled, but only in low, moist, fertile soil. Very few of them germinated. The few roots secured did not grow well and most of them did not survive the hot and dry summer months. During the succeeding winter every root left was killed. As at its best this variety produces but a small quantity of green forage or hay, it is not recommended to central Texas stockmen or farmers.

PEAS AND BEANS.

COWPEA (*Vigna catjang*).

During the season of 1899 about sixteen varieties of cowpeas were tested. In every case the results were satisfactory. The seeds were planted in drills 3 feet apart, and as long as the season permitted the ground was kept stirred between the rows and about the roots. The plantings were all made the same day—April 11. Good stands were secured, the plants grew well from the start, and all of them matured seeds in spite of the very unfavorable season. Early in August it was seen that the vines were suffering and shedding their leaves. Most of them were cut, cured, and baled, and a comparatively large quantity of an excellent quality of hay was saved, and through the following winter was fed to and greedily eaten by cattle. Some of the vines were cut with their fully formed but unripe fruit pods attached. These pods cured readily with the stems and leaves and added no little to the fattening value of the hay. Some seeds of each variety were saved and planted in the spring of 1900. The general results were about the same as were secured in the former season. It is difficult to determine as to the relative values of the many varieties tested, as all of them were satisfactory. It is well known that the cowpea as a soiling crop is one of the best. As it produces in abundance fruit rich in all the special elements of a first-class stock feed, it is highly valued by those who know it best. The green-vine product is one of the richest of stock foods, and when cured is a very valuable hay. Central Texas stockmen and farmers are earnestly recommended to sow considerable areas of their farms each year to cowpeas. They can hardly make a mistake in the matter of variety.

Field Pea.

A few seeds of the Canada field pea were planted April 10, 1899, in the grass garden. Only a poor stand was secured, but the vines grew well, with a great deal of stem that was covered with leaves, bloomed well, and matured abundantly. They had practically run their course before the hot and dry summer winds commenced. The vines and seeds are very similar in appearance to the well-known English or garden pea. In the early spring of 1900 some of the peas saved from the crop of 1899 were sown in drills 3 feet apart, very thick in the rows, the purpose being to test the value of this variety for forage purposes. An excellent stand was secured, and the vines grew luxuriantly and fruited satisfactorily. When the pods were fully formed, but before the peas were ripe, the vines were cut, cured without difficulty, with the seed pods attached, and baled. The bales were examined during the winter following and the hay fed to a horse and a cow, each of which ate it with relish. Some of the vines and seed pods were fed green to cattle and a horse and were eaten with relish by all. As this variety of pea will produce an abundant and early crop for forage or seed, it will pay those having stock to feed to cultivate it.

Gram or Chick Pea (*Cicer arietinum*).

This is a curious-looking plant, but little known in this country, though it has been cultivated in Asia Minor during the past thirty centuries, its seeds being highly valued as a cattle food and as an article of human diet. The plant itself, however, is unsuited for green forage, as it is covered with a clammy exudation consisting largely of oxalic acid. A few of the peas were drilled in the grass garden and practically every one of them germinated. The plants quickly grew to a height of 18 to 20 inches and matured an excellent crop of seeds.

METCALF BEAN (*Phaseolus retusus*).

The writer hesitates to express an opinion as to the merits of this perennial legume. It had been represented to him as being a very valuable native of western Texas and New Mexico, with large drought-resistant qualities, and he was anxious to give it every advantage in the matter of cultivation. A few seeds were received from the Division of Agrostology and a few from Mr. James K. Metcalf, of Silver City, N. Mex., who was the first to introduce the plant into cultivation several years ago. Plantings were made March 21, April 11, and March 18, 1899. Good stands were secured, and the vines quickly grew to be from 8 to 12 feet long, spreading out in every direction from the crown of the root, much like sweet-potato vines. In fact the vine growth was remarkably strong, but not a blossom appeared. Early in August the vines began to languish under the hot and dry weather, and by September 1 all the roots were dead. As the result of correspondence with Mr. Metcalf, and at his suggestion, they were planted in 1900 in rows 8 feet apart in hills every 8 to 10 feet. As in 1899, a good stand of strong vines was secured, and very late in the fall a few blossoms formed, but too late even to develop into pods. Finding that there would be no bean crop, most of the vines were cut; some were feed green to cattle and were eaten readily by them, and some were cured and baled. The bales were opened in February and March, 1901, and the hay fed to a horse, which ate it with evident enjoyment. As the result of these experiments, extending through the seasons, one very dry and the other (1900) a very favorable one, the conclusion was reached that for hay and soiling purposes the Metcalf bean is good in central Texas, but the seasons are not long enough to insure a bean crop.

SOY BEAN (*Glycine hispida*).

This is one of the oldest cultivated forage plants. It has been grown in China and Japan for many centuries, but was introduced into this country only a few years ago. The seeds are very rich in fats and nitrogenous compounds, and it is claimed that next to the peanut it is the richest of all the legumes in the digestibility of its food constituents. Three varieties were tested in 1899 in the station garden. The early variety grew from 8 to 12 inches, and the yield of seeds was satisfactory. The medium variety grew to be about as tall as the early variety and produced a very abundant crop of seeds. The late variety grew to be about 24 to 30 inches high, but matured only a few seeds. In 1900 seeds saved in 1899 were planted. The results were about as in the previous year, except that the vine growth was stronger, due to the fact that the season was in every way more favorable. The bean yield of the early and medium varieties was large, but that of the late variety was practically nothing. Many pods of the last formed, but the beans did not mature before the frosts caught them. When cut before the pods are ripe the cured product becomes a very rich and in every way superior stock food. Too much can hardly be said in favor of this valuable forage plant, and, as it is as easily grown in central Texas as cornfield black-eyed peas, and the ripe bean is among the richest of concentrated foods, it should be largely cultivated by those having stock to feed. (See fig. 5.)

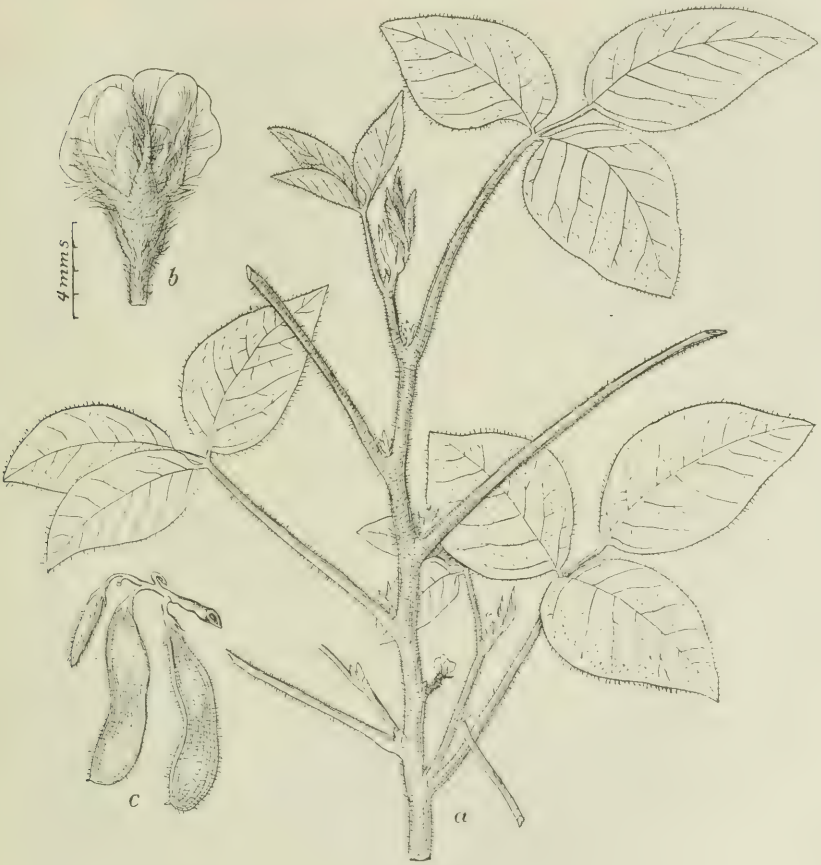


FIG. 5.—Soy bean.

SULLA (*Hedysarum coronarium*).

This is another of the perennial legumes that is well worth the consideration of central Texas stockmen and farmers. It has been extensively cultivated in southern Italy, where it is a native, upward of two hundred and fifty years, and was introduced into this country but a few years ago. Seeds received from the Division of Agrostology were sown in the station garden May 4, 1899, on the side of a dry, gravelly hill. The stand secured was satisfactory, and by July 15 the plants were 6 to 12 inches high, and the roots had grown down into the ground to corresponding depths. About that time, as the result of the very severe drought of that year, the plants began to give way, and by September were apparently dead. October 26 the heavy autumn rains began and they revived at once, and by November 10 a new growth of plants 3 to 6 inches high had been made. They continued to grow until December, and in January, 1900, the crowns of the roots were still green. In February they gave way as the result of the heavy frosts. The plant growth was vigorous, and late in the season the plants, which were from 18 to 24 and in a few instances 30 inches high, were covered with a rich crimson flower that was showy and beautiful. No seeds matured, however. As to its feeding qualities, it compares favorably with the best of the clovers and alfalfas and, in central Texas, produces satisfactory crops.

VELVET BEAN (*Mucuna utilis*).

This legume is attracting a great deal of attention, especially in the extreme Southern States, where the soil and climate seem to be specially favorable to its development. In central Texas it is a valuable forage plant, but too far north for it to mature seeds satisfactorily. It was carefully and thoroughly tested in the station garden in 1899 and 1900, and the results each year were practically the same. The vine growth was phenomenally strong, and while there was a profusion of blossoms, and in 1900 a considerable seed-pod formation, not one matured bean was secured. The vines proved to possess abundant drought-resistant qualities, and, in fact, withstood the hot, dry weather during both summers into August better than anything grown in the station garden, except possibly the soy bean. In 1900 the seasons were more favorable than in the preceding year and the vines continued green well into October. Some of the vines grew to be 15 to 20 feet long, with a heavy leafage. In the latter part of September, 1900, several rows were cut, and the vines were cured and baled. The bales of the cured product kept sweet, and were fed to stock in January and February, 1901. It is confidently believed that it may pay those having live stock to be wintered to cultivate velvet bean, not only for green forage, but for its hay value, as far north as central Texas. (See Pl. II, fig. 2.)

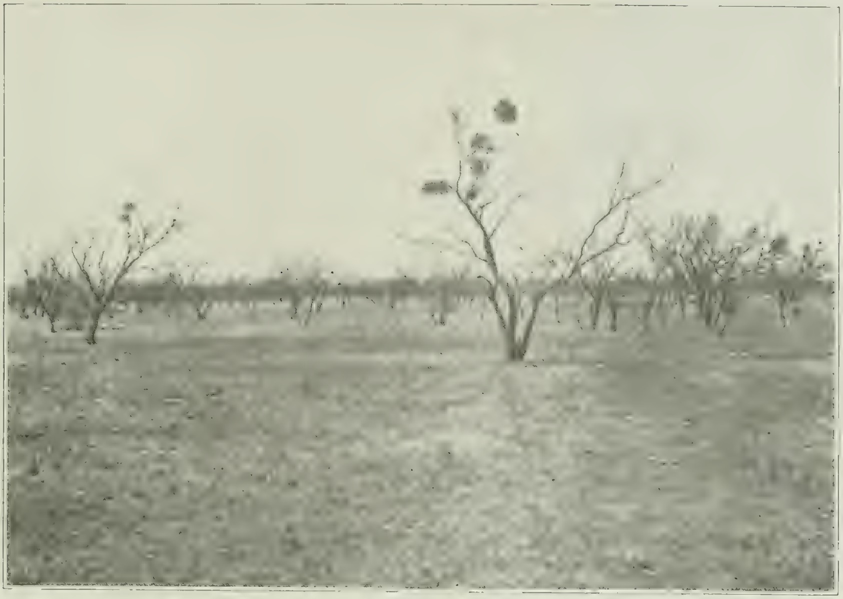


FIG. 1.—RANGE NEAR ABILENE, WHERE THE EXPERIMENTS WERE CONDUCTED, SHOWING CHARACTERISTIC GROWTH OF MESQUITE BEAN.

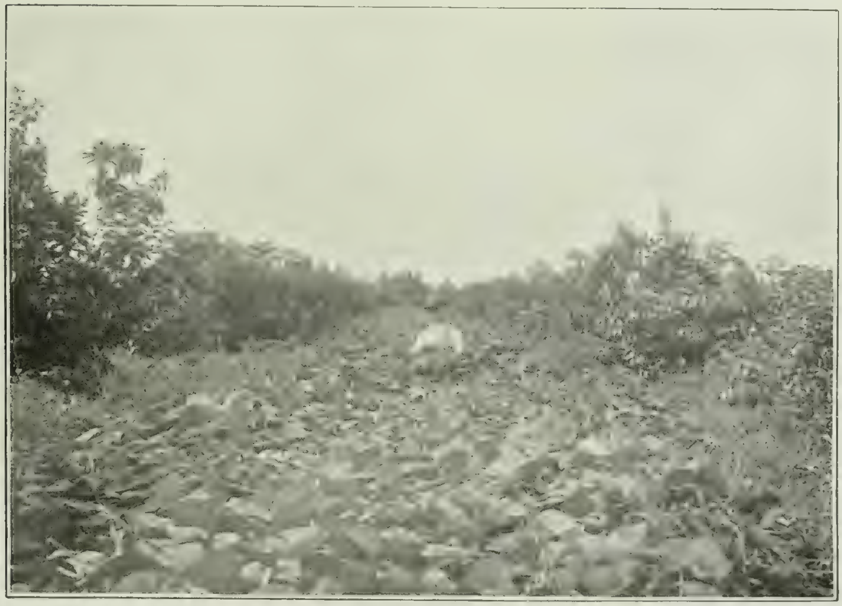


FIG. 2.—GROWTH OF VELVET BEAN.

VETCHES.

Comparatively few stockmen and farmers of central Texas know anything about the vetches, and yet more than one variety, natives to the section, are growing on the ranges and in their fields, and constitute factors of no small importance in the make-up of their pastures.

Spring Vetch (*Vicia sativa*).

Seeds of this variety were tested in the station garden in 1899. A first planting was made in February, but on account of the ground being cold, and continuing so until in March, few seeds germinated. Later plantings were made March 17 and April 10, good stands were secured, and the plants grew rapidly to 18 to 20 inches in length, and matured good crops of seed. A cutting could have been made during June and early in July.

Hairy Vetch (*Vicia villosa*).

This variety was also tested in the station garden in 1899, the plantings being the same dates as those of the spring vetch. The results were substantially the same with both varieties. A cutting of the hairy vetch was cured and baled. The hay was soft and rich, and the yield (estimated) was at the rate of 1¼ to 1½ tons per acre. The soil where it grew was not rich. The nutritive value of the hay is very high. As in fertile soils from 2 to 4 tons per acre can be grown, it will pay those having live stock to feed to cultivate it, and also the spring vetch.

Other Forage Plants.

With a view to determine the value of several of the grain crops generally grown in central Texas, especially for forage and hay purposes, a number of interesting tests were made with more or less satisfactory results.

Common Oats and Wheat.

It is a well-known fact that when oats are cut just after heading they make hay of the finest quality. It is also a well-known fact that a crop can be grown in central Texas during the winter on ground from which corn has been gathered, and can be harvested in time for planting the ground in the spring. It is further known that during the years when the rainfall is normal large yields (3 to 5 tons per acre) of the straw can be grown on the fertile lands of this section. The pressing needs among stockmen and farmers are for early spring pastures and for plants that will yield, under wider cultivation, good hay crops. The time has passed for any class of live stock to be left to "rustle" on the range for their winter feed. The enterprising stockgrower now recognizes the necessity for providing winter forage for his stock, both as a matter of business and as a matter of humanity. With a view to assisting stockmen of central Texas and farmers in their efforts in the direction indicated, the writer made a large number of tests in the station garden during 1900 to determine the value of oats and wheat for hay and green forage purposes. He secured many different varieties from the Department of Agriculture and from other sources, planted the seeds in drills, cultivated the ground thoroughly, had the crop cut and cured when the seeds were in dough state, and baled the hay product. The results were in every way successful. The seasons were favorable; the yield in every case was considerable; the hay had a rich color, and in the bales presented an attractive appearance and kept as well as any other hay. During the following winter the bales were opened and fed to stock and every straw of it was greedily eaten. Mr. P. O. Forbus, foreman of the station working force, has grown during the last two or three years a turf oats which has not only afforded a good winter pasture for his stock, but has yielded fairly good grain crops later. He has not cut the crop for hay, but is satisfied, as the result of the station experiment of 1900, that in that shape the crop will be worth much more to him than as a grain crop. Mr. W. J. Warder, late a stockman and farmer of California, still later of the Abilene country, and now at El Paso, Tex., is authority for the statement that several years ago in California, realizing that the drought coming on was likely to ruin his wheat crop, he had the entire field cut just after the heading. He handled the green product precisely as if it had been grass, had no difficulty in curing it, and sold the hay product for more than he could have realized for a good grain crop. Mr. C. W. Merchant, of Abilene, Tex., is making a specialty of cultivating both oats and wheat expressly for green winter forage and only incidentally with a view to grain crops. Central Texas stockmen and farmers are reasonably certain, four out of every five years, to secure a good oats-hay crop, even if they shall fail to secure a good grain crop. A wheat crop for hay purposes is not quite so reliable, but is worth the annual effort, and the writer strongly recommends that such be made.

PEANUTS (*Arachis hypogæa*).

As above suggested, reliable forage plants which can be converted into good hay are what is much needed by stockmen and farmers in central Texas counties. They are reasonably certain each year to have grass for their live stock from the time the earliest range grasses (as needle grass) begin to green out, well into the early winter. After the range grasses are frost-bitten, however, they are often troubled to procure winter feed for stock without having to pay ruinous prices. It will pay them to go into the work of experimenting in the direction indicated with a view to helping themselves out. They can supply themselves, certainly, abundantly, and reasonably as far as cost is concerned. The question is, Will they take the trouble? Many of them will be surprised when informed that the well-known peanut is one of the most valuable fodder plants for this section of Texas. They may safely use either one of the two very distinct varieties, "common," which produces the peanut of commerce, or the "Spanish." It may also surprise them to be told that peanut-vine hay is about as nutritious as red clover and richer than timothy, and that peanut meal makes a richer stock food than cotton-seed meal. Yet these are facts. Several tests were made in the station garden in 1900 to determine how peanut hay could be utilized to the best advantage. Seeds of both of the varieties were secured and planted in rows so as to admit of cultivating the soil. Being dry, rather sandy upland, good stands and good yields of both vines and nuts were secured. The Spanish variety gave the better results so far as the quantity of vines was concerned; but the common variety gave a better yield of fruit. When the pods were about half grown the vines were pulled up, turned with the nuts to the sun, allowed to cure, and when cured, were thrown into shocks, and later made into bales. Several months thereafter the baled products were examined and vines and nuts found to be sweet, and when fed to cattle, every stem, leaf, and nut was eaten. For the benefit of those who may care to look into the subject, it is recommended that they send to the Department of Agriculture for Farmers' Bulletin No. 25, Peanuts: Culture and Uses; study it carefully, and then put in good-sized fields of peanuts, not for the matured peanuts, but solely with the view to using the vines and half-green nuts for forage purposes. It will pay well in years when there is a normal amount of rainfall.

RAPE (*Brassica napus*).

This succulent and nutritious forage plant, which is closely related to the Swede turnip, can be easily and profitably grown in the deep, rich, warm loams and sandy soils to be found in all the counties of central Texas. It makes an excellent feed for either cattle or sheep, and will stand a great deal of hot and dry weather. Of the several varieties that are well known in the United States and Canada, the Dwarf Essex is the most widely cultivated. Seeds of this variety were sown April 18, 1899, in the grass garden, in low, rather moist, but not very fertile soil. A good stand was secured and the plants grew vigorously, but they were attacked by prairie dogs and jack rabbits before the garden could be closed in with wire netting, and not a plant was saved. In 1900 plantings were made March 19 and 26 in the same kind of soil, and a good stand secured. The plants quickly grew 12 to 24 inches high, and when other things were suffering during the summer on account of the hot and dry winds, the rape plants held their own surprisingly well.

Saltbushes (*Atriplex*).

The several tests made of this forage plant in the station garden have been entirely satisfactory. Seeds of several varieties were planted March 16 and April 18, 1899, but only a few of them germinated. Of Nelson's saltbush (*Atriplex pabularis*) and of Nuttall's saltbush (*A. nuttallii*) a few plants each were secured. About a dozen weak plants of the shad scale (*A. canescens*) started, but they soon died. Of all the varieties tested, the annual saltbush from Australia (*A. holocarpa*) gave the best results. The growth was not large, being only from 12 to 24 inches high, but the seed development was surprisingly great. Seeds of all the varieties named, except the shad scale, formed and matured through the long and hot summer; not a few, but thousands of them. Twice in July and August the seeds were carefully stripped from the plants, but as fast as the earlier seeds were gathered others grew and developed, ripened, and fell off, covering the ground under each bush. The plants continued green until early in December, but by the 15th of the month, as the result of some rather severe frosts and freezes, they were nearly all dead. In 1900, each of the above-named varieties was again tested and the tests confirmed in the mind of the writer the opinions formed of them the season before. Seeds of the Australian saltbush (*Atriplex semibaccata*) were received from the Division of Agrostology and were sown both in March and April. The previous year the seeds had been planted rather deep, and it is believed that the thin stands were in consequence thereof. In 1900 the seeds of the variety under special consideration were sown in shallow drills and were lightly covered. An excellent stand was the result, and the plants were vigorous from the start. As this is a procumbent or prostrate variety, it will be better to refer to its vines, rather than to its plants. They spread out in every direction from the crowns of the roots, from 2 to 4 feet, and produced an abundant leafage and a large number of seeds. Specimen plants, the roots of which were about 2 feet long and the stems nearly 4 feet long, were sent to the Agrostologist. During the long, hot, and dry spells of that year all of the varieties named showed excellent drought resistant properties, but the Autralian saltbush particularly held its own most tenaciously. The Australian saltbush is known to be an excellent plant for soiling sheep, and sheep dealers in California use it a great deal in that way. It is stated on excellent authority that it develops better on alkali than on other soils; hence stockmen and farmers in the Pecos Valley country, where the soil is strongly impregnated with soda salts, will do well to test it fully. The recommendation is also made to those in other sections of Texas to sow fields to it, as on the ordinary soils it is reasonably certain to produce satisfactory results.

Sanfoin (*Onobrychis sativa*).

This is a deep-rooted perennial that was tested in 1899 and 1900 in the station garden with satisfactory results. Seeds which were sown May 4, 1899, in thin, gravelly soil on a hillside germinated well, and the plants grew to be 12 to 18 inches high. During the severe drought of that year they held their own better than the clovers, vetches, or alfalfas, and quite as well as the sulla. When the autumn rains began (October 26), the roots which had failed to some extent soon revived, and before the winter freezes began a rather vigorous new growth had developed. The lighter frosts and freezes did not injure the plants at all, but during the months of January and February, 1901, there was some severe weather which injured the foliage. By March, however, the roots again began to revive, and March 19 the new growth was from 6 to 10 inches long. Plants once well rooted will live a great many years if the soil is rich and the seasons favorable. Sanfoin produces a fair quantity of an excellent quality of forage that continues green during the late autumn and the early winter months, when green forage is scarce. It stands droughts remarkably well, and though the plants when young are liable to be winterkilled, when they are well protected they will not be killed in central Texas by any but very severe freezes. It is claimed for it that it is a superior hay plant, but the tests in the station garden rather indicate that it is much more valuable for pasture purposes. For the reasons stated its cultivation is recommended.

Sweet Potato (*Convolvulus edulis*).

An interesting experiment was made in 1900 in connection with the station work with a view to determine if sweet-potato vines could be successfully baled and in that shape kept sweet for the purpose of winter feeding. From a field belonging to Mr. P. O. Forbus, near the station, some of them were secured when the tubers were almost or quite matured. They were cured about as readily as the vines of the several varieties of peas, but in curing they shrunk very much in bulk, and when cured were not nearly sufficient in quantity to make up a bale. The dry product, however, was kept dry, and late in the autumn was fed to cattle, which ate it quite greedily. The vines are known to be rich in fattening properties, and since the plant can be grown very cheaply throughout central Texas and converted into hay with but little trouble, and doubtless can be baled and in that shape as easily preserved as alfafa, vetch, or pea vines, it is suggested that stockmen and farmers should save every vine grown by them for forage purposes.

Tallow Weed (*Actinella linearifolia*).

The writer has long known this excellent forage plant in Texas. He first saw it in Tom Green, Concho, and Crockett counties when his own stock fed on pastures of it, and demonstrated its wonderful fattening properties. Every sheep-raiser and cow-man in the stock-raising counties of Texas knows about it and values it highly for the forage it supplies. They call it tallow weed for the reason, as they give it, that the plant will put more tallow on the kidneys of cattle and other stock in a given time than any other native stuff, green or cured. As it makes its appearance on the range very early in the spring before anything else greens out, it has a value distinctly its own. It often grows 12 to 18 inches high on the range, has fragrant blossoms which develop into a rich seed head, and lives into the early summer months, but gives way under the influence of extremely long hot and dry periods. It revives in the autumn months, and frequently continues to furnish some green forage in the early winter months. The writer found another related species (*Amblyolepis setigera*) in the pasture of Mr. D. W. Middleton, of Abilene, Tex., growing luxuriantly in October, 1898. During the months of October and November, 1899, and in November, 1900, in a pasture of about 10 acres, between Abilene and the station, a fair proportion of the plants were green. Tests were made in the grass garden in 1899 and again in 1900 to determine its value as a hay plant. The plants were cut and efforts were made to cure them, but they molded and soured. As a green-forage plant it is one of the very best for central Texas, but as a hay plant it is extremely doubtful if it can be satisfactorily handled.

Teosinte (*Euchlæna luxurians*).

So much has been claimed for this very superior forage plant that much interest is being manifested in regard to it by stockmen and farmers of central Texas. Tests were made in the station garden to determine what it is really worth for live-stock purposes. Seeds received from the Agrostologist were planted in drills and in hills 4 feet apart each way April 10, 1898. By July 1 the plants had met in the rows; by July 15 the severe drought of that year was on, and by August 15 the plants had suffered seriously. The drought was not broken until October 26, by which time the plants and roots had failed entirely. The stalks grew 5 to 6 feet high and there was an abundance of fodder. Early in June some stalks were cut, cured, and baled, and months later were examined and found to be sweet. Some teosinte roots in the station garden, in spite of the drought, put out from 25 to 40 or more stalks, and it is confidently believed that a yield of 10 to 15 tons per acre can be secured in any fertile valley of central Texas. As the hay is much softer and more easily cured, baled, and handled than any of the sorghums known in the section, and as in years of normal rainfall it will certainly do well, stockmen and farmers should plant considerable areas of their fields to teosinte. Efforts were made in 1900 to secure some seeds with the view to making some further tests with it, but they were received too late. It may be considered reasonably certain that it will not mature seeds so far north; but the astonishingly large quantity of stalks and

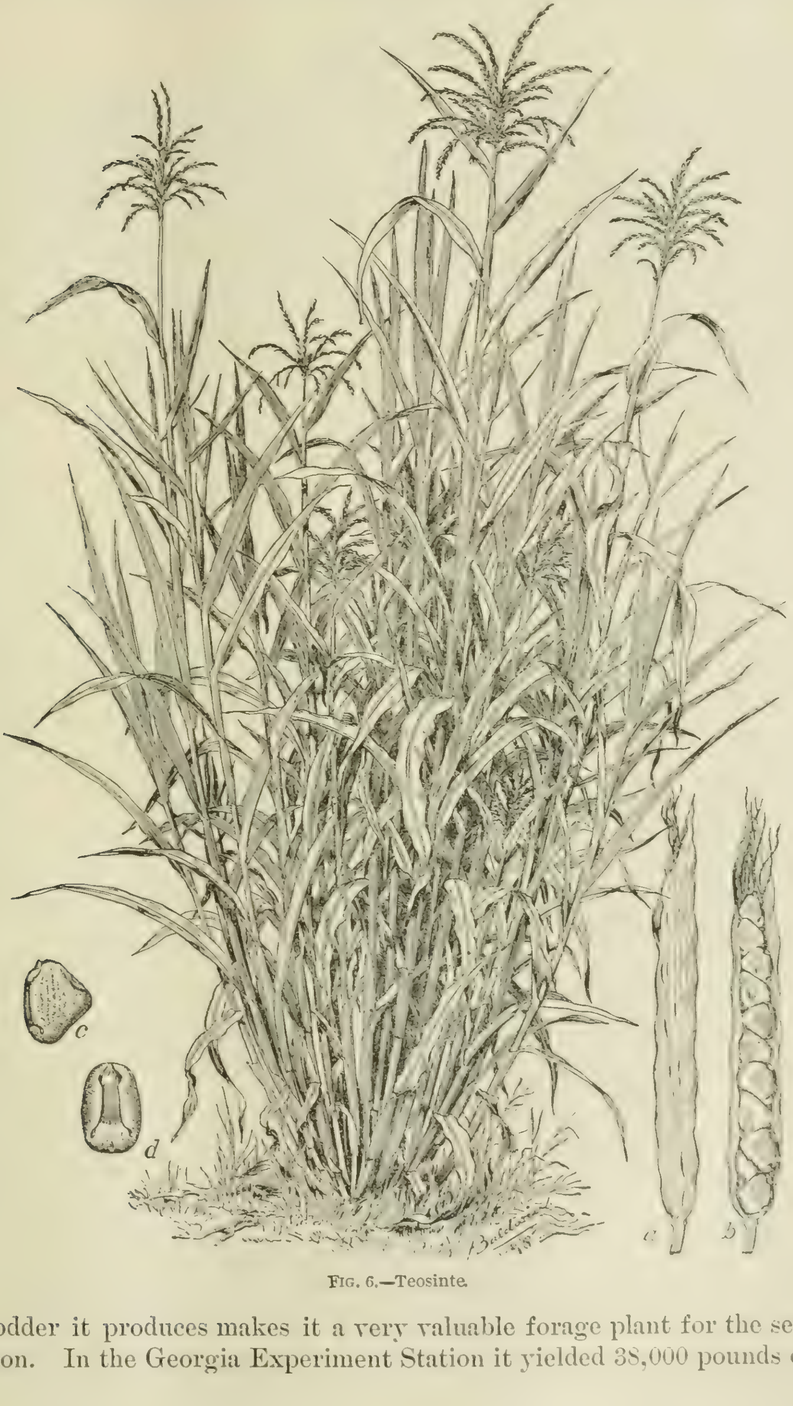


FIG. 6.—Teosinte.

fodder it produces makes it a very valuable forage plant for the section. In the Georgia Experiment Station it yielded 38,000 pounds of green forage per acre, 40,000 pounds at the Mississippi station, and in Louisiana over 100,000 pounds. During droughty seasons it will not do well, and it will not pay to plant it in poor soil. (See fig. 6.)

CONCLUSION.

The foregoing statements report several fairly successful experiments made at the grass and forage plant station during three years from March 19, 1898, to March 19, 1901. As to the very large number of tests that did not give satisfactory results, it is hardly necessary to go into details. The impracticability of doing so will be understood in the light of the statement that quite 1,500 tests altogether were made during the term mentioned. In 1900, and to March 19, 1901, there were kept with the experimental work alone 656 separate accounts.

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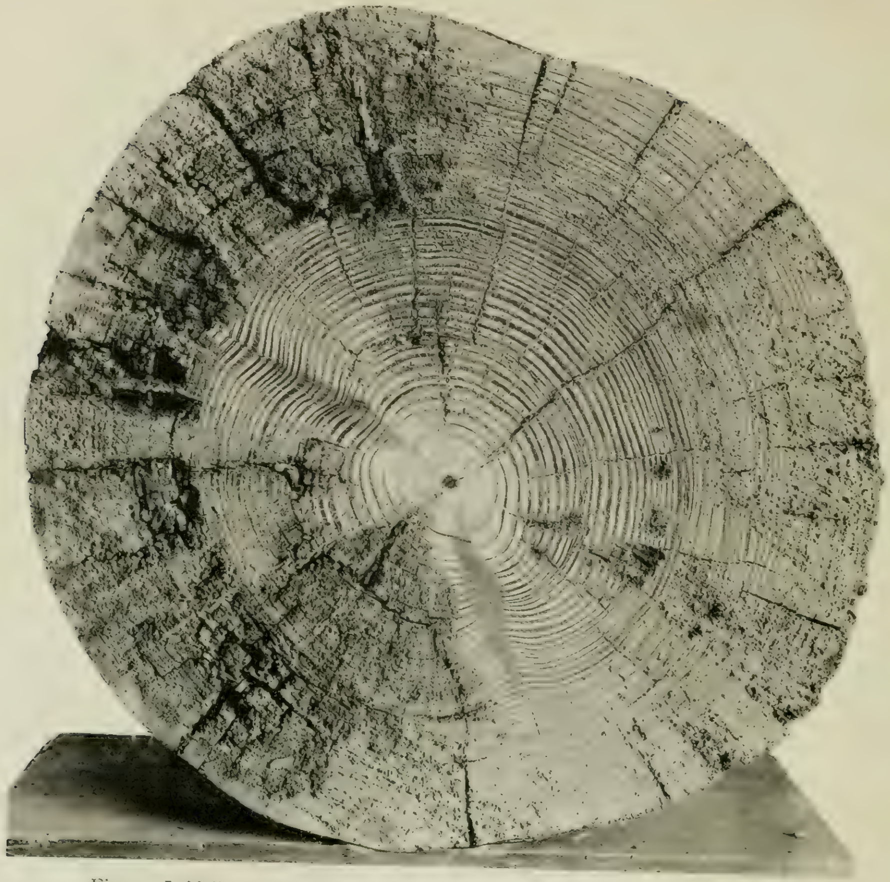

Fig. 1. Loblolly pine pile, from southern Texas, showing decay after 12 months.

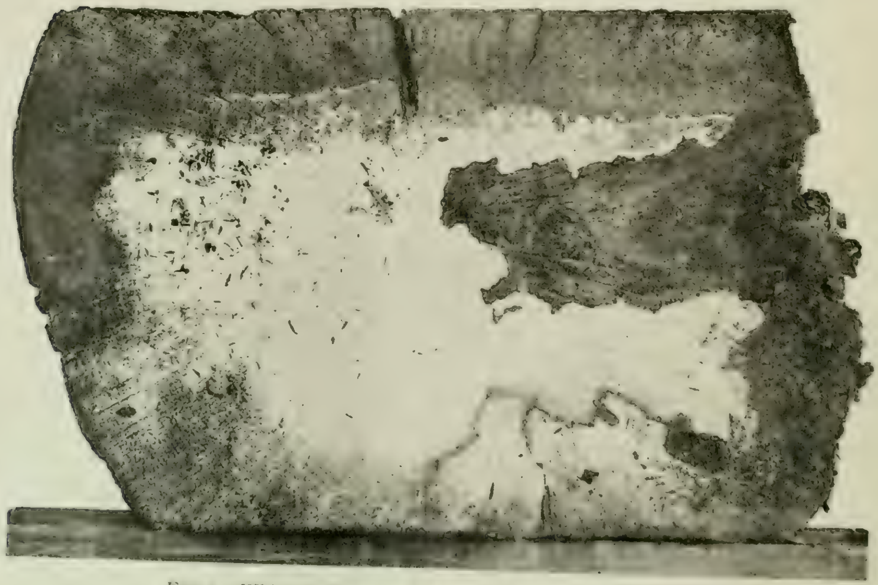

Fig. 2. White oak tie, showing growth of destructive fungus.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN No. 14.

B. T. GALLOWAY, Chief.

THE DECAY OF TIMBER

AND

METHODS OF PREVENTING IT.

BY

HERMANN VON SCHRENK,

Instructor in Henry Shaw School of Botany, and Special Agent in charge of Mississippi Valley Laboratory,

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

Issued March 25, 1902.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 8, 1902.

Sir: I have the honor to transmit herewith a paper on The Decay of Timber and Methods of Preventing It, and respectfully recommend that it be published as No. 14 of the Bureau series of bulletins. The paper was prepared by Dr. Hermann von Schrenk, special agent, in charge of Mississippi Valley laboratory, Vegetable Pathological and Physiological Investigations, and was submitted by the Pathologist and Physiologist.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The annual destruction by decay of forest timber and of timber used for construction purposes, such as railroad ties, fence posts, telegraph poles, bridge timber, etc., is almost beyond computation, and is one of the greatest drains on the timber resources of the country. Several years ago this Office undertook an investigation of the causes of such destruction, and the general awakening of interest in forestry has called special attention to the importance and necessity of our work in this line. For a number of years the railroads have been investigating methods of preserving ties, and early in our work we were led to examine the progress made by them as a basis for the general investigation of the subject of preservation of construction timber.

Dr. Hermann von Schrenk, instructor in the Henry Shaw School of Botany, and special agent in charge of the Mississippi Valley laboratory of Vegetable Pathological and Physiological Investigations, has been actively engaged in the work for several years, and has collected much valuable information in connection with it both in this country and in Europe. The present report, which is a basis for much more extensive investigations planned for the coming year, embraces a discussion of the factors which cause the decay of wood, an account of the various methods used in this country and abroad for preserving timber, and also an account of original work conducted to test various methods.

The Department is under obligations to the railroads for furnishing Dr. von Schrenk facilities for conducting his investigations, and also to many others who have aided him in his work.

The work is being pushed vigorously, in coöperation with the Bureau of Forestry, which is actively aiding us in our investigations in this line, and it is believed it will appeal to the country as a whole, as all interests and classes are affected, directly or indirectly, by the losses occasioned by the decay of construction timber.

It is to be hoped also that as a result of the experiments planned much standing timber of varieties now worthless for construction purposes, owing to its rapid decay, may be made commercially valuable by preservative processes.

Albert F. Woods,
Pathologist and Physiologist.

Office of the Pathologist and Physiologist,
Washington, D. C., January 9, 1902.

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THE DECAY OF TIMBER AND METHODS OF PREVENTING IT.

INTRODUCTION.

The various uses to which wood is put at this time are so numerous that an enormous amount of timber is required annually to fill the demand. Building materials, railway ties, fence posts, telegraph poles, etc., make up the larger part of the wood cut. Figures as to the actual amount of timber cut are difficult to obtain, and after all they give the average reader very little intelligent information. The individual is interested in so far as he wishes to be assured that there is enough timber for him now and that there will be some in the future, both at a reasonable price. One can, however, give an approximate idea of the amount used by considering that the railroads alone renew over 110,000,000 ties every year, and that one telephone company (the Bell Telephone Company) has now in use some 6,000,000 poles, varying from 20 to 90 feet in length, of which some 500,000 were added during the past year. In 1887 the number of tie renewals was estimated as about 70,000,000.

It is very evident that the amount of timber removed from our forests every year is enormous, and with the extension of the arts and industries it is easy to foresee that the future will show a very marked increase over the present consumption. Although it is not probable that we are to face a timber famine in the near future, it can hardly be denied that the removal of such quantities of timber as are now coming from the forests every year can not fail to make a deep impression on the forest resources of any country, no matter how large the reserve may be.

During the last thirty years there has been a constant appreciation in the prices of timber in many sections of the country. This appreciation has not occurred uniformly; in fact, some classes of timber are cheaper to-day than they were thirty years ago.

It is perhaps hazardous to explain why, with the constantly decreasing supply, such timbers are cheaper to-day. It is presumably more a matter of transportation than anything else. With increased railroad construction, sections of timber land have become readily accessible which years ago were distant from centers of distribution. The great supply of the past was drawn chiefly from sources along lines of railway or contiguous to them. As these became exhausted the sections back from the roads were tapped. The timber brought out cost more than that immediately on the line, until a branch was built into this new section, and then the cost fell again.

It is not fair, therefore, to judge of any future supply by a mere comparison of prices. This is obvious when one remembers that the source of white oak, for instance, in the early period of railway construction was chiefly in Pennsylvanina, Ohio, Indiana, and Wisconsin. These States furnish a very small amount of the supply at present. It now comes from southern Missouri, Arkansas, Kentucky, and Tennessee. Even the most sanguine lumber contractor will not admit of more than fifteen years' supply from southern Missouri, and ten years will probably be more nearly correct. The price of oak timber is not so very much greater than it was ten years ago, and yet the visible supply is very small at this time. Many other sections of the country once well timbered are now bare, to wit sections of Pennsylvania, Wisconsin, Michigan, and Minnesota.

Those who say, therefore, that there is no need of considering the question of future supply because timber is still cheap are simply voluntarily ignoring what to most observers is a very obvious situation.

Looking for a moment at the tie situation, we find that the railroads of the Eastern States are drawing a large part of their supply from the pine forests of the South and from Canadian points, the lines of the north-central West are beginning to bring timber from the Pacific coast, while those of the Central States are drawing on the recently tapped forests of the lower Mississippi Valley. The changes which occur in the sources of timber supply are slow, and it is impossible to state at this time what the situation is likely to be twenty years hence. Our knowledge of the timber now standing is very inexact, and it is to be hoped that ere long some steps may be taken to obtain more reliable data on this subject. The sources of supply will within an appreciable time be shifted without doubt from the Northern and Central States to those of the far South and of the Pacific coast.

There is now no longer any question as to the desirability of a rational discussion as to where the great volume of timber is to come from in the future. We must find out how we can best take measures to insure an adequate supply for all time, and at the same time at reasonable cost. The discussion and study of this problem is the province of the forester of to-day. One phase of this subject leads toward establishing methods of cutting timber along lines which will insure a regular supply. Another phase will occupy itself with establishing new centers of supply by caring for or planting denuded or treeless areas. A third phase will be devoted toward finding out how we may increase the length of service of the material now at hand.

Timber, when it is removed from the forests, decays sooner or later, and has to be replaced. The replacing involves the cost of new timber, the cost of replacing, and in many instances the cost engendered by the disturbance. By increasing the length of service of timber, we not only make it cheaper, but we use less of it. Increasing the length of life of timber is, therefore, one way of conserving the existing timber supply and of lessening the cost of the timber actually used. This has been realized for a long time, as instanced by the first forestry bulletin published by this Department. In this Mr. Kern points out very clearly the advantage to be derived by securing a longer life for structural timber. This increase in the length of life applies to timber used for ties, for buildings, greenhouse and other construction, for fence posts, in fact wherever wood is used. Longer life may be attained in two ways—by placing wood under such natural conditions that decay becomes impossible, or by preserving the wood in one way or another.

During the past hundred years or more the highest grade timbers have been used at all times wherever they could be obtained. In the North the white pine was used exclusively, while the spruce was left standing. Now that the pine is almost gone, the spruce is in demand, although it is in most respects a very much inferior timber.

There are in many parts of the United States many kinds of timber which are for one reason or another not being used at the present time. We find, for instance, that the so-called high-grade timbers have always been cut out first, leaving the less valuable kinds standing. In the central West the inferior oaks were left and only the white oak was cut; in the North the tamarack and balsam fir remained after the removal of the white oak and spruce; while on the Pacific coast the hemlock and lodgepole pines are ignored because of the red fir and bull pine. Where the strength requirements form secondary features, as in ties, the resistance to decay has often kept these woods in the lower class. One of the problems of the future will be how to make use of these timbers. They can be bought at a low price, for many large tracts are within easy reach of transportation lines. If some method can be found by which tamarack, the swamp oak, and the loblolly and lodgepole pines can be used for ties, leaving the white oak and other expensive timbers for higher grade structural material, a great forward step will have been taken in the utilization of our forest resources and in their more economical handling.

In the following pages some brief considerations will be presented, calling attention to the knowledge which we have concerning the problem of timber preservation at this date. Much of the matter presented has been referred to before, both in reports of this Department and elsewhere, but so little headway has been made in the practical application of the older reports that it has been thought advisable to go over the whole problem again at this time, when the problem is becoming so much more vital. The writer wishes to refer to the papers by Dudley, Flad, Chanute, Curtis, and others mentioned below, which may be read at this time with profit.

It will be noted that much attention has been paid to railway ties in this report. The reason for this is that the railway companies have been and still are among the largest consumers of timber in the United States. But, aside from that, they have been most active in the study of preservative processes in all countries. The position of a tie in the roadbed is one most unfavorable to the long life of wood. It presents, on that account, one of the best means for studying the changes which take place in wood, and how these may best be prevented. That which applies to wood in the form of a tie is, as a rule, applicable to all forms of structural timber, telegraph and telephone poles, mine timbers, fence posts, bridge and building timbers, greenhouse material, etc.

SCOPE OF THIS REPORT.

The subject will be considered under the following heads:

(1) Structure of timber (wood cells, heartwood, and sapwood) and its mechanical and chemical nature.

(2) Factors which cause decay of wood.

(3) Timber preservation.

(4) Account of an experiment to test the value of preservative processes.

(5) Report of an inspection trip to Europe for the purpose of investigating the results of timber impregnation.

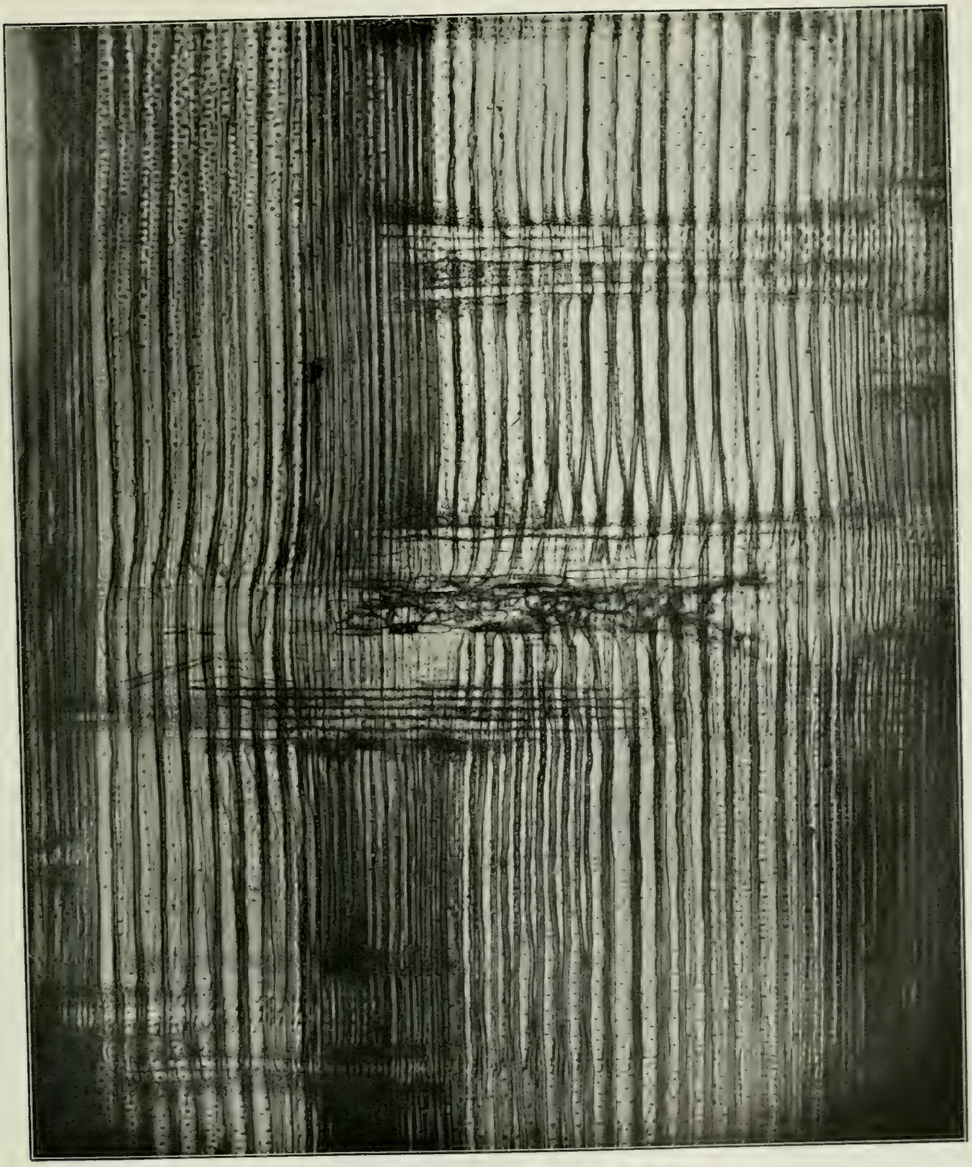
(6) Conclusions and recommendations.

STRUCTURE OF TIMBER.

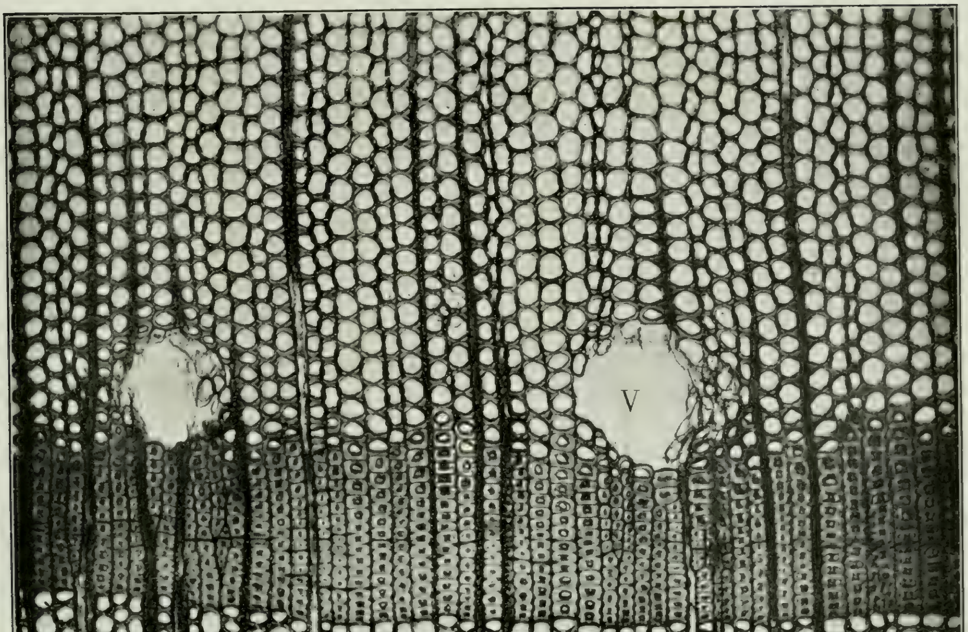
Before describing the various agents which destroy wood fiber, it may be well to consider briefly the character, structural and chemical, of wood. It will be found that a good understanding of the impregnating problems can be obtained only after a clear comprehension of the various chemical and physical features of woody matter itself, and woody matter as a part of a piece of timber.

WOOD CELLS, WOOD FIBERS, ETC.

Wood is composed of a series of closed tubes extending parallel to the long axis of a tree trunk (Pl. II). These tubes are firmly united laterally, and are so arranged as to fit into one another endwise, so as to form a splice. This will be comprehended by a study of the figure on the accompanying plate (Pl. II), which represents a longitudinal section of a piece of yellow pine. It will be noted that the tubes are of varying sizes, some with large diameters, others smaller, and that there is a regular succession of larger and smaller ones. (See also Pl. III, which represents a cross section of the same wood.) The larger tubes are found in the spring wood, when growth is most active. With the approach of summer, the tubes of smaller diameter and thicker walls are formed. A group of the spring tubes, together with the adjoining summer tubes, represents the growth of one year,



RADIAL SECTION OF WOOD OF LONGLEAF PINE (PINUS PALUSTRIS).



CROSS SECTION OF WOOD OF LONGLEAF PINE (PINUS PALUSTRIS).

and is termed an annual ring. One of these rings is usually formed every year, and only under most exceptional circumstances are two produced in one year.

The tubes, called by various names (wood elements, vessels, tracheids), are of various kinds. They differ in their diameter, in the thickness of their walls, and in the marking of the walls. Some are perfectly smooth, slender fibers (fig. 1); others are marked in a peculiar way (fig. 2). All wood cells are formed by a series of thin-walled cells lying immediately under the bark—the cambium layer. These cells divide and form wood cells toward the inner side and form bark toward the outer side. The young wood cell is filled with a semi-liquid mass called protoplasm. Very soon after its formation there is deposited on the thin wall of the new cell from the protoplasm a second layer called the thickening layer. In some cells this is deposited evenly; in others in a manner so as to leave spaces or surfaces. When this thickening has gone on for some time it ceases, and we have then a mature wood cell. The spaces and surfaces left unthickened appear as markings on the wall. A brief study of the accompanying figures will make this clear. Figure 3 shows the most complex form, found in the wood of pines and all other coniferous woods. It will be noted that in none of these cases is an absolute hole formed between two adjoining cells. There is always a thin membrane between the cells, and only when the cells have been dead for a very long period do these fine membranes ever break. In the pines, spruces, etc., the small plates in the pits effectively close the opening, even in old cells.

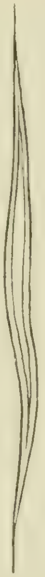


FIG. 1.—Wood fiber.

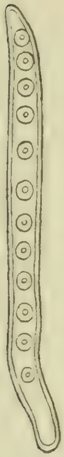


FIG. 2.—Wood fiber (tracheid) with pitted walls.

The wood tubes differ very much in size and their method of arrangement. In the hardwoods one finds some very large tubes, called ducts, which are sometimes arranged in rows at the beginning of a year's growth, as in the ash; in other cases they are scattered through the entire wood ring, as in the oaks (Pls. V, VI, and VII), birches, chestnuts, etc. They are entirely absent in all coniferous woods. The length of the wood fibers differs. In the pines, etc., they are usually comparatively short, while in those of the oak they are much longer. As the cells grow older they lose their content of protoplasm, and become filled with air and various infiltrating substances (resins, gums, etc.), which will be referred to again.

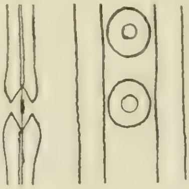


FIG. 3.—Showing nature of the thin places in cells of coniferous wood.

In most woods a series of plates extends radially outward from the pith, known as pith rays or medullary rays. These rays are composed of short, thin-walled cells, which serve to conduct water and food substances. The rays vary in diameter and height, as may be seen from Plate IV, where the lens-shaped cell groups represent cross sections of pith rays.

On Plate VII the very large group of cells in the middle of the figure, marked "M," is one of the large rays which are very characteristic of oak wood.

Besides the large ducts mentioned above found in hardwood trees, one meets with large ducts in some of the conifers, which secrete resin and conduct it from place to place. They are known as resin ducts. (v, Pls. III and IV.)

CHEMICAL NATURE OF WOOD.

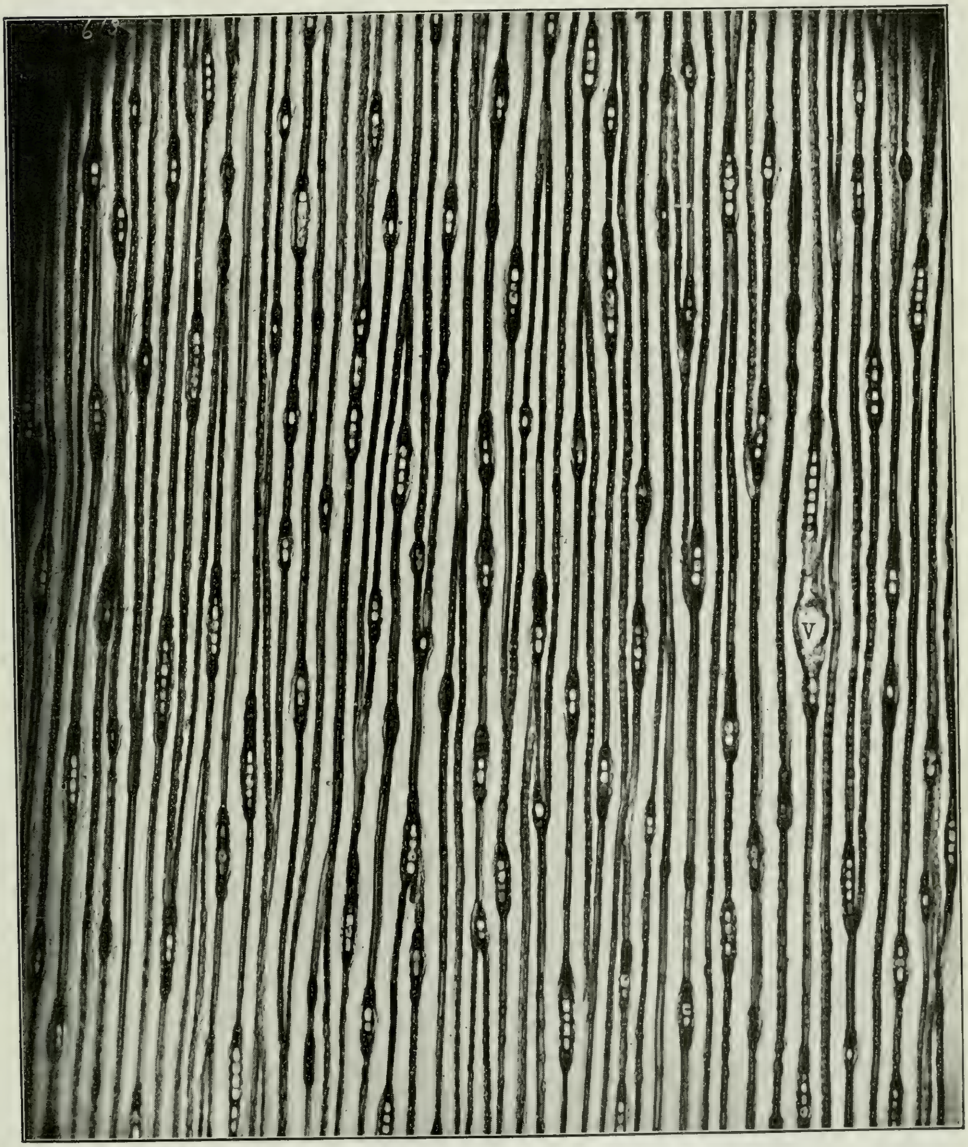
The chemical composition of wood is little understood. It will be sufficient for the present purpose to say that the fine, original membrane of the cell and the groundwork of the thickening is composed of cellulose. This cellulose is infiltrated with various materials, collectively known as lignin. This lignin is dissolved out by various fungi, leaving the cellulose skeleton, and vice versa, as can be seen from figures 10 and 11.

MECHANICAL NATURE OF WOOD.

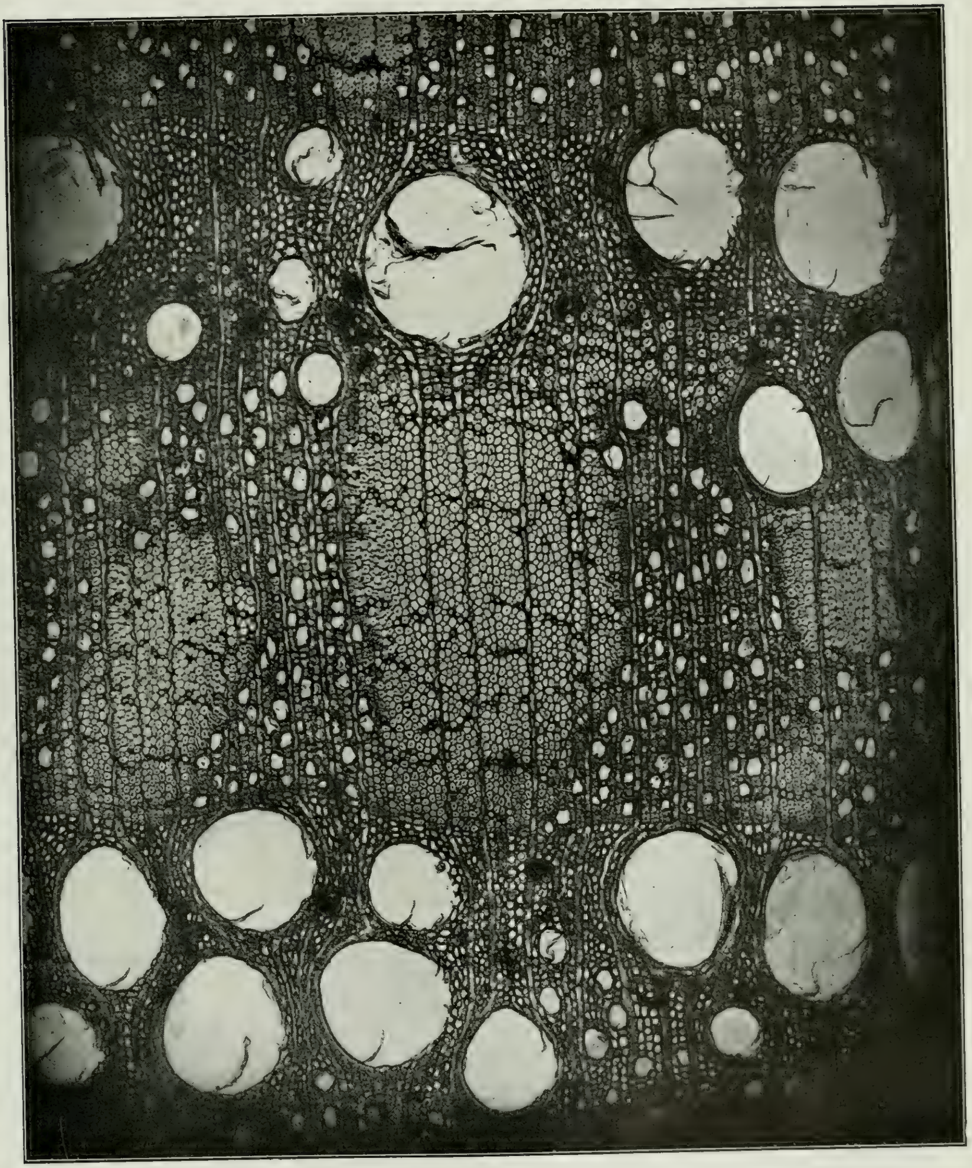
The mechanical properties of wood fibers must be mentioned in this place. There has been much discussion as to the effect upon wood cells of high pressures, such as are applied in forcing preservatives into wood. In the living condition the internal pressure exerted upon the walls because of osmotic forces often reaches 5 atmospheres and more. It is therefore highly improbable that any pressure brought to bear on wood fiber by forcing a liquid into it would be sufficient to injure the same in any way. Wood fiber of pine is capable of withstanding a crushing load of 4,000 pounds per square inch, applied endwise.

LIFE OF THE WOOD CELLS.

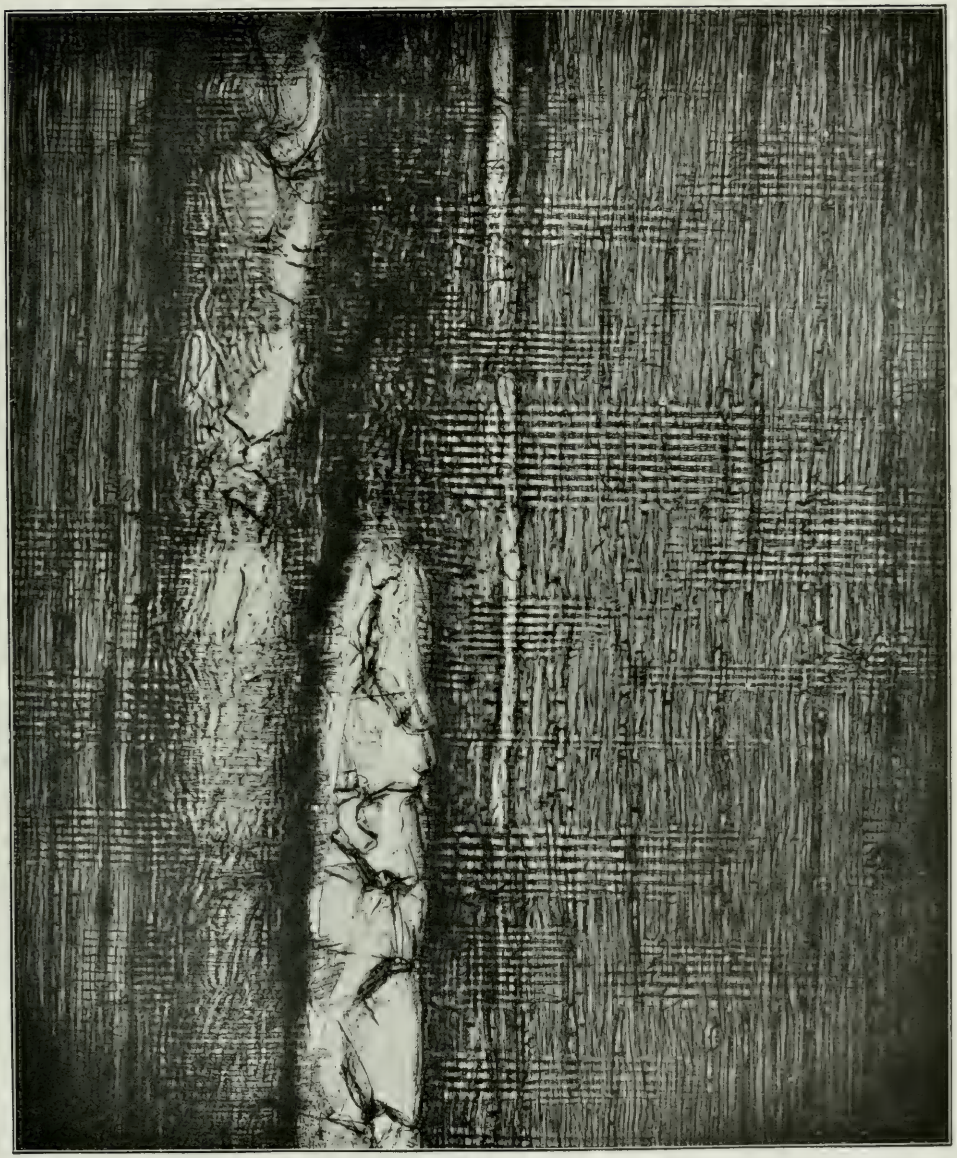
Reference has been made above to the manner in which wood cells are formed by the cambium layer. It is very essential that the relation of the cells to one another be considered, particularly in relation to the circulation of water and the so-called life of the tree. The outermost rings of wood in a tree trunk usually constitute the living elements. It is in them that the circulation of water takes place, particularly the transfer of the same from the roots to the crown above. The wood cells are filled with protoplasm and with various food substances, such as sugars, starches, and oils. The medullary rays are particularly rich in these substances. As one goes toward the center of the trunk one will find that the wood cells gradually lose their con-



TANGENTIAL SECTION OF WOOD OF LONGLEAF PINE (PINUS PALUSTRIS).

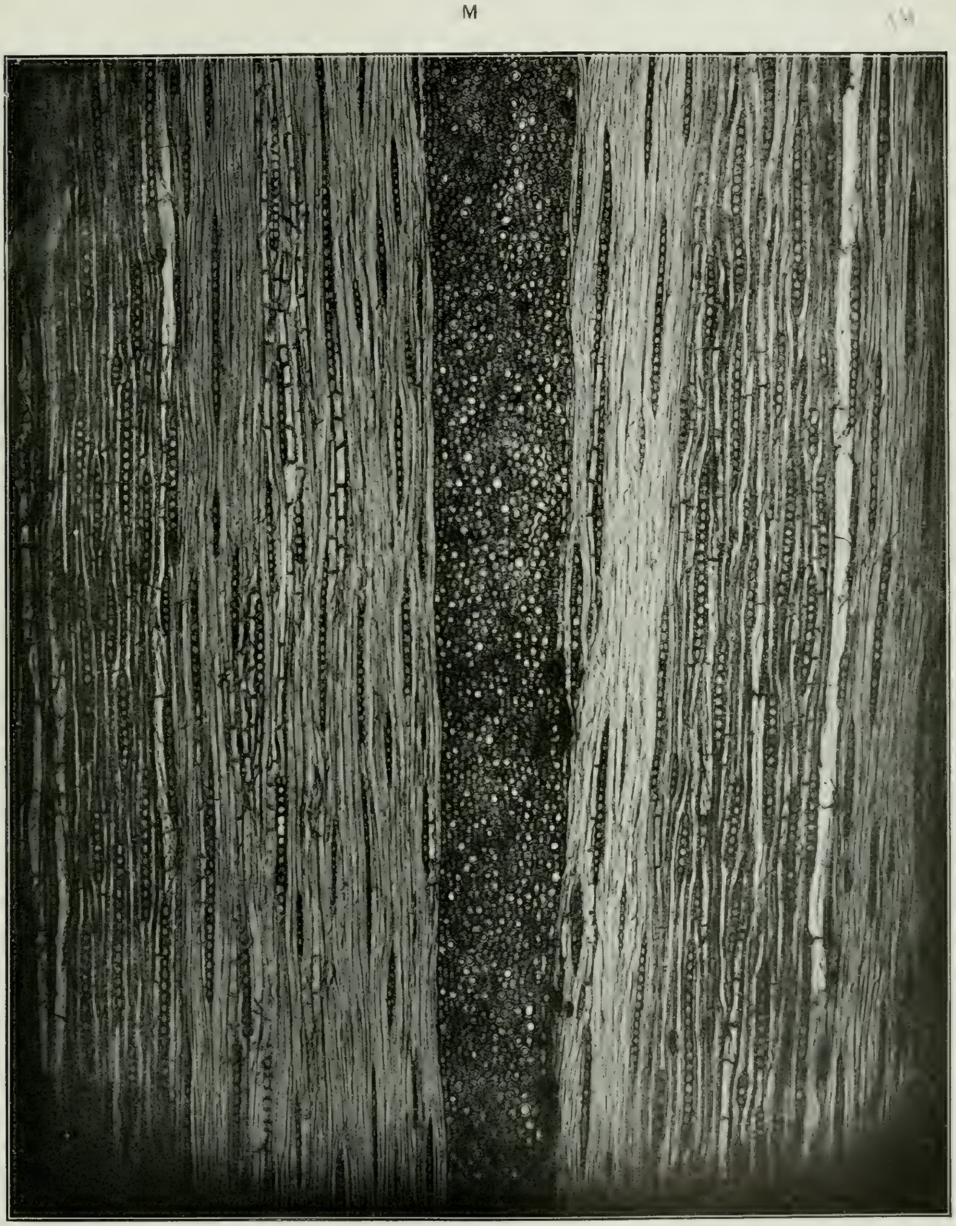


CROSS SECTION OF WOOD OF WHITE OAK.



RADIAL SECTION OF WOOD OF WHITE OAK.

PLATE VII.



TANGENTIAL SECTION OF WOOD OF WHITE OAK.

tents and become filled with air. They are then mature; their walls have attained their maximum thickness and strength. They begin to make reservoirs for the deposition of various substances—gums, resins, aromatic substances of various kinds—which remain in the cells, but take no part in the life of the tree. These cells are then, to all intents and purposes, dead. The medullary-ray cells remain alive much longer. Going inward, one finds that they at first lose their sugars, then the starch reserve, and lastly the oil products. It will appear from this that the boundary line between the living wood and the dead elements is no very sharp one.

The water passes through the walls of the newer wood cells readily, and continues to do so for a considerable period after the cell contents have disappeared. It is only when the walls of the cells become thoroughly infiltrated with the resins, gums, etc., that the water transmission comes to a stop. The depth to which the living elements in a tree trunk go depends entirely on the kind of tree. In some trees, for instance the maple and the beech, the living elements extend through many rings, as many as 30, counting from the bark inward, while with trees like the locust or red cedar the number of rings with living cells is very small, not exceeding 14 in the locust, for instance.

HEART AND SAP WOOD.

It appears from the preceding, therefore, that the outer living part of the tree differs materially from the inner dead parts in the presence of large quantities of food materials, oils, starches, sugars, and nitrogenous substances, and in its readiness to transmit water, while the inner parts have larger quantities of infiltrated substances in the walls of the wood cells. These considerations bring one to the question of heart and sap wood. Much has been written on this subject, but we have as yet no very clear conception of what makes heart or sap wood. Broadly stated, the sapwood is composed of the living parts, or, better still, of those outer parts of a tree which allow of free passage of water, while the heartwood consists of the dead inner parts, which serve mainly as a support to hold the crown and in which, because of profound changes in the walls of the wood cells, water no longer travels with ease. The heartwood of most trees is easily distinguished from the sapwood by its darker color and by the presence of various coloring substances. The appearance of these in the wood often indicates which wood is heartwood, which sapwood. The change from sapwood to heartwood is apparently a sudden one. It does not take place in one ring every year, but skips many years frequently, so that 8 to 10 rings or more may become heartwood in one year. Then, again, one side of a tree may change to heartwood, including more annual rings than another—that is, one ring may be heartwood at one point and sapwood at another.

For practical purposes, however, the differences between heart and sap wood are sufficiently well marked. Heartwood lasts longer than sapwood, and it is stronger. In some trees the heartwood resists decay for hundreds of years during the life of the tree, as in the giant trees, while in others, willow and maple, for example, it offers no resistance, apparently, to decay.

The varying resistance of woods to bacteria and fungi will be discussed below at greater length. Having described the structure of wood, one now comes to a consideration of decay.

FACTORS WHICH CAUSE THE DECAY OF WOOD.

GENERAL REMARKS.

By decay one understands at this time the gradual change which any substance undergoes in breaking up into simpler substances. The decaying body changes in its physical and chemical nature, and when it is entirely decayed, the remaining materials bear no resemblance to the original. The breaking-down changes were formerly supposed to be due to some spontaneous process working within the changing substance. The great German chemist, Liebig, was the author of a theory which dominated all others during the middle of the nineteenth century. He maintained that the change in organic matter was a form of slow combustion, which he called "eremacausis." The processes of change were induced by oxygen, much as iron changes to rust. He stoutly denied that bacteria, fungi, or other living agencies had anything to do with decay. Not until the epoch-making researches of Pasteur and his school was it understood that the changes which accompany decay were due to the activity of lower animals and plants. These low organisms, living on or within the substances, use a portion of the same for food, and by removing some of the elements from the substratum they break up the complex chemical compounds. This results in the liberation of various gases and in the phenomena which are known collectively as rotting or decay. It is probable that with the majority of organic substances, that is, substances of plant or animal origin, no change takes place in their chemical nature without the active working of some living organism.

AGENTS WHICH CAUSE DECAY.

The living organisms which cause decay of timber may be insects, bacteria, or fungi. Insects bore holes into sound timber, and in many cases they may riddle a stick completely, so that it falls to pieces. The work of the white ants or termites, which is so destructive to all timbers in warmer climates, is of this character. Then there is a class of beetles, the larvæ and adults of which bore in wood as soon as the same is dry enough to allow them to enter. The decay of structural timber is, however, brought about most frequently by either bacteria or fungi.

Bacteria are low plants which multiply with great rapidity. A single individual divides into two, and these two each divide again. As their method of action on wood is, so far as known, about the same as with the fungi, the two will be considered together.

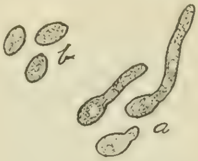


FIG. 4.—*a*, Fungus spores; *b*, the same, germinating.

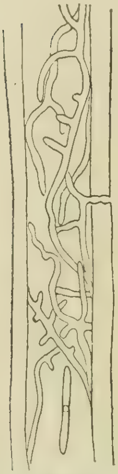


FIG. 5.—Mycelium of a fungus attacking a cell wall.

Fungi are low plants, consisting of colorless, fine threads, called hyphæ, many hyphæ making up the mycelium. All fungi grow on either dead or living organic matter, from which they remove certain parts.

The mycelium starts from a single spore (fig. 4*a*). The spore, when brought under favorable conditions, sprouts or germinates, sending forth a single thread or hypha (fig. 4*b*). This thread branches and rebranches quickly. The various hyphæ creep through the tissues of the substratum upon which they are growing and absorb the materials necessary for their growth. In living cells they attack the protoplasmic contents—the starches, sugars, and oils. In dead cells they attack the cell walls (fig. 5). After sufficient food has been absorbed some hyphæ form the fruiting body, which bears a crop of spores (fig. 6). The fruiting bodies of the fungi which destroy timber are elaborate structures, which may be formed once every year, or when once started may continue to grow in size from year to year. They form the familiar punk knots, punks, conchs, toadstools, frog stools, or mushrooms found on live and dead timber in the forest. Many of these fungi attack wood. They are readily distinguished by their fruiting bodies, but since the manner in which these fungi work is, so far as we know, approximately the same for all, it is hardly necessary to attend much to the form. Figure 6 shows the cross section of one of these punks discharging spores. On the under side one finds a series of tubes (fig. 7), along the edges of which long rows of threads are arranged. A small part of one of these walls is shown in figure 8. Some of these threads extend out into the tube, and on each one finds four spores. When ripe these fall off and come out of the tubes in clouds (fig. 6). The wind carries them in all directions, and when they fall on wood they sprout, as shown in figure 4*b*.

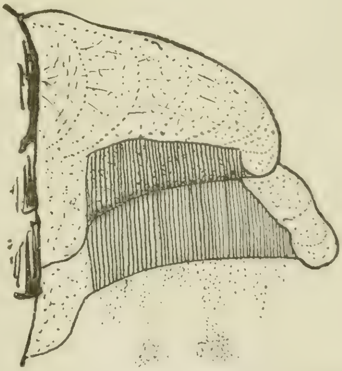


FIG. 6.—Fruiting body of a wood-destroying fungus.

HOW FUNGI AND BACTERIA GROW.

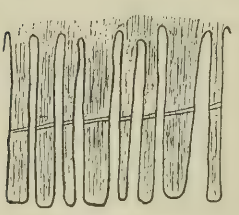


Fig. 7.—Enlarged section of lower (spore-bearing) part of fig. 6.

The fungi and bacteria that destroy wood obtain their food by breaking up the complex chemical compounds of which wood is composed into simpler substances, utilizing some of these and leaving some either as gases or solids. A crude idea of the working of a fungus may be obtained by comparing it to a wheat plant. The wheat plant takes something from the soil and something from the air. After it has taken these substances from the soil and air they are changed. When the wheat plant has accumulated enough food it forms seeds. Just so the fungus. It takes all of its food from the wood, and leaves a different substance, rotted wood, behind. When ready it forms a seed plant, the punk or toadstool. It obtains its food by giving off peculiar liquids, known as ferments or enzymes, which have the power of transforming wood fiber into substances which the fungus uses for food. Their action usually results in whole or partial solution of the substance attacked. Sugars and starches are attacked by different ferments; the sugars may be absorbed by the fungus directly, or changed to some more easily digested sugar. The starches are changed to sugar and are then absorbed. The nitrogenous substances undergo similar changes. Wood fiber may be dissolved entirely by the ferments, or only the cellulose or lignin elements. Some mycelia excrete ferments which attack only cellulose, others only the lignin, while others attack starches and sugars. When one part of the wood substance is removed it is no longer wood. The chemical changes have brought about profound physical changes. The hard, elastic wood fibers have become a soft mushy mass, or a dry, brittle substance which falls to pieces at the slightest touch. Figures 9–11 show a number of structural changes in the cell walls. At first the hyphæ simply puncture the cell walls here and there (fig. 9). As they grow more numerous more holes are made, and often enough so that the tensile strength vanishes

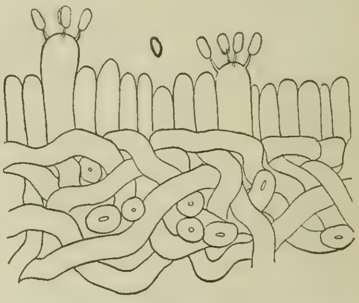


Fig. 8.—Highly magnified spore-bearing surface of fungus shown in fig. 6.

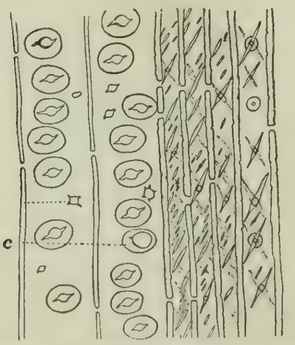


Fig. 9.—Cell walls punctured by fungous hyphæ.

almost entirely. Then again, by the solution of the cellulose or lignin, cracks may form (fig. 10). Some fungi dissolve out the middle lamella (fig. 11), so that the various wood cells fall apart. It will be evident that wood when attacked in this manner very soon loses its properties, and before long changes into a mass of unconnected pieces. Figure 12 shows how even the hardest wood is gradually dissolved. It is this change which one terms decay.

RATE OF GROWTH AND DECAY.

The best conditions for growth of fungi and bacteria are an abundant food supply and a certain amount of heat and moisture. One point requires particular attention. Fungi are living organisms, which, in common with other living things, grow and develop at a certain rate, which has its limit. Beyond a certain point at which optimum conditions have been reached, it will not be possible to increase the rate of development. It ought to be said that there is considerable range between ordinary and optimum conditions. To use a simile, it is not possible to make a child of 5 grow to be as large as a man of 30 years in two years. Just so is it impossible to force the development of a fungus which takes two years for its development into a period of two months.

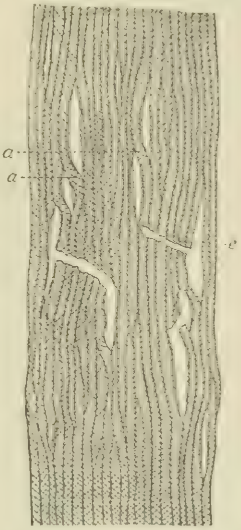


FIG. 10.—Cracks in wood due to the solvent action of fungi.

Optimum conditions vary with the different fungi and bacteria. Some grow best with a large supply of oxygen; others grow best without it. Some require sugars and starches, others do not. All, however, require water. Where there is no water, there will be no fungous or bacterial growth. The so-called "dry rot" fungi require a certain amount of moisture. It is a very erroneous, though widespread idea, that they grow in perfectly dry situations.

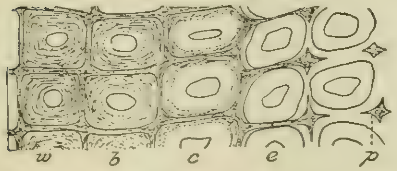


FIG. 11.—Cross section of wood, highly magnified, showing solvent action of fungi.

Much of the rotting of timber could be prevented by heeding this simple fact—that without water there will be no rot. For this reason a tie in a well-drained roadbed will last ever so much longer than its neighbor in a badly drained ballast, in spite of the absence of treatment, the presence of fungi, and ignoring the variability in the timber itself. Wherever organic food is stored, there the bacteria and fungi are sure to grow with great rapidity if moisture is present. This is one of the reasons why sapwood rots so much faster than heartwood. The medullary rays and wood elements of the sapwood have been described as full of protoplasm and reserve sugars, starches, oils, etc. After the death of a tree these cells are rapidly invaded by hyphæ, which flourish in the sapwood, and soon bring about its entire dissolution. The heartwood offers no such basis for the beginning of fungus growth. It is furthermore protected by antiseptic bodies, such as various resins, the tannins, etc. The sapwood admits of the more ready circulation of water, and in that way favors the rapid development of the fungus threads. What has been said of fungi is also true for bacteria. So far as we know they also produce ferments which destroy the starches and oils in the wood, also the wood fiber. Very little is as yet known about the bacteria which destroy wood. For the present purpose it is sufficient to know that they do so in a manner similar to the fungi.

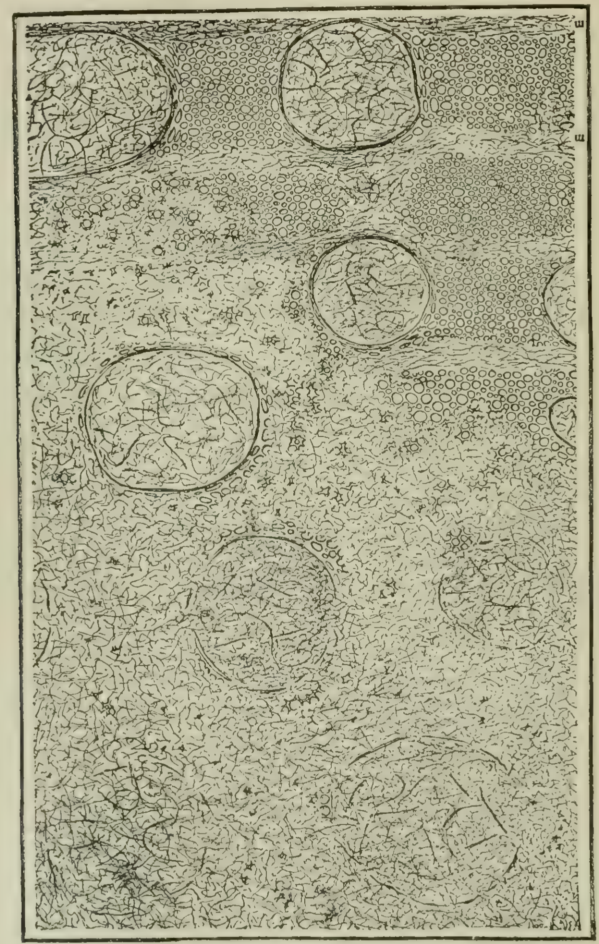


FIG. 12.—Advanced stage of decay of locust timber due to fungi.

Attention is here called to a rather surprising statement made by

Mr. Herzenstein in reply to Dr. Dudley's discussion of the manner in which fungi destroy timber. He says[a] that the fungi (by which he appears to mean the "punks") appear only on ties which have come out of the track; and, again, that "the vibrations caused by trains prevent, if not the formation of filaments, at least the growth of the fungus itself." Such statements are so obviously false and misleading that no attention would have been paid to them here if they had not come from one whose words might be taken seriously. At this time we know absolutely that fungi cause decay of wood; furthermore, that the "punks" which Mr. Herzenstein seems to lay so much stress on are simply the fruiting bodies of these fungi; and, again, everyone knows to their own regret that "vibrations caused by trains" do not stop the rot of ties in the track. It would be a pertinent question to ask Mr. Herzenstein, if he is so sure that the vibrations stop the growth of the fungi, why he thinks any injection of salts necessary.

NATURAL RESISTANCE OF TIMBER.

Dry wood will resist the attacks of destructive agents, such as fungi and bacteria, for indefinite periods of time. The timbers in many old buildings have been in position for hundreds of years. The writer examined some larch wood obtained from an old chapel in Switzerland which was supposed to be about 500 years old. It was hard and sound and showed no signs of deterioration.

Engineers have made use of this principle now and then by employing several timbers instead of one large one. It was found that a timber 12 by 12 inches would not last nearly as long as one composed of four timbers 12 by 3 inches. When more widely appreciated, this principle will no doubt be applied still more. In general, all conditions which favor drying and keeping wood dry will tend to prolong its life.

Wood completely immersed in water will not decay. The supply of oxygen necessary for the development of fungi is cut off. Decay in piles, for instance, takes place near the point where the pile emerges from the water. In fence posts and telegraph poles the decay usually starts just below the surface of the soil. Above the ground the wood remains dry, while at the extreme base there is only a limited supply of oxygen. Where there is some oxygen and some moisture, i. e., near the surface of the ground, there the rot sets in.

SAWN VERSUS HEWN TIMBER.

A word may be said here concerning a question which is as yet but imperfectly understood, but which has already caused much discussion. There appears to be a well-defined opinion that so-called hewn timber will last longer than sawn timber. Many railroad companies specify that their ties shall be hewn from young trees, i. e., be pole ties. Because of this practice millions of young trees are cut annually from forests where the older timber remains standing.

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[a] Bulletin of the International Railway Congress (English edition), 15: No. 10, October, 1901, p. 2429.

The reasons why hewn timber should last longer are difficult to define. It may be that the sawing, passing as it does in one line, irrespective of the "grain," cuts across many fibers, thus presenting many openings where the water can pass in readily. The sawing exposes the more resistant and less resistant parts of annual rings in an irregular manner. Then, again, the sawn surface is rough; many fibers are torn away partially. This gives the wood a felty surface, which holds water readily. The hewn timber, on the other hand, has no fibers exposed, for the ax causes the chips to split off "along the lines of the grain." It shows a smooth surface of either spring or summer wood, generally the latter.

The objection sometimes made that the hewn ties cut from a young tree are firmer and naturally more resistant because the wood is younger appears to have no good foundation.

Whatever the relative value of sawn and hewn timber may be—a point which needs careful investigation—it becomes a matter of small importance when timber is impregnated. The impregnated wood would be influenced only to a very small extent by such differences as are spoken of above. The results of many years' practice are not easily laid by, and it will probably require a practical demonstration to convince many of the correctness of the contention that, when properly treated, a sawn timber is just as good as a hewn one. Hewing is a very wasteful process. It is slow and not economic and, above all, it requires the use of young timber, to the exclusion of that which is older and often more durable.

SEASONED VERSUS GREEN TIMBER.

As the presence of a certain amount of moisture is indispensable for the growth of the destructive agents, it follows readily that seasoned timber will last longer than green timber. Although this is so simple a matter and one generally appreciated, it is surprising how rarely it is heeded by those who use timber. The chief excuse made is that it takes time to season timber. Many say that they are in doubt as to whether the expense involved in keeping timber is warranted by increased length of life. Some practical experiments on a large scale ought to be made to convince those who still doubt the advisability of long seasoning. The writer ventures to assert that few realize how much longer a piece of seasoned wood will resist the action of decaying agents than a similar piece of green wood.

The Russian railway authorities have found that their seasoned oak ties last practically as long as the same timber impregnated with zinc chloride and laid shortly after treatment, and on that account do not treat their oak. A good deal depends upon the manner in which wood is piled. The Europeans pile ties so as to give the maximum amount of air space around each tie. They make piles with several hundred and often several thousand ties in one pile (Pl. VIII, fig. 2). (Compare with this Pl. IX, showing an American pile.) The ties are hoisted into position with a donkey engine, and when seasoned are either treated or in some cases laid directly. The piles are located so as to give the greatest exposure to the sun's rays and with reference to prevailing winds. The length of time allowed for seasoning will vary much with the climate and must be determined separately for each locality. The present practice of exposing timbers to decay very soon after cutting is extremely wasteful and could with ease be modified. Of course that means an accumulation of material for a year or more in advance, but this ought to be no serious objection when one takes into account the great amount saved by such a step.

RACES OF WOOD.

Susceptibility to decay and comparative resistance to decay vary with the different kinds of timber. The qualities which determine the greater resistance to fungus attack are as yet almost unknown. Hardness, density, specific gravity, tensile strength, are factors which seem to have no influence one way or the other. Some of the tropical timbers which are extremely hard and heavy decay in exceedingly short periods of time, while equally hard woods last very long. The teak wood of India is a notable example of endurance, and is highly esteemed on this account. Among the timbers of the United States the hard, strong white oak decays far more rapidly than the light, porous cypress. The resistance is, furthermore, not confined to broad-leaved trees or conifers. The tamarack and hemlock decay rapidly, while the cypress and cedar are lasting timbers; just so we find elm and birch short lived, the locust long lived. There are certain groups of timber which resemble one another in being highly resistant to decay. Some of these are the red cedar (*Juniperus virginiana* and *Juniperus barbadensis*), the cypress (*Taxodium distichum*), the incense cedar (*Libocedrus decurrens*), the big trees and redwoods (*Sequoia sempervirens* and *Sequoia washingtoniana*), and the arbor vitæ (*Thuja occidentalis* and *Thuja plicata*). The lasting powers of these woods, as is well known, exceed those of any other of our native woods. All of them are usually classed as soft woods. The reason for their resistance is probably to be sought for in the presence of some substances in the wood which give it protection against fungi. All of these timbers come from trees of ancient lineage which have persisted down to the present time and are able to grow in our forests with more recent trees.

VARIABILITY IN TIMBER.

A striking feature which must be mentioned at this point is the great variability in all respects of timber of the same kind taken from different trees. Those who have impregnated timber are constantly confronted with this fact, for they find "that very rarely are two pieces of wood alike." This variability is one of the attributes, as now viewed, of all living matter. There are hardly two trees which grow under exactly the same conditions. We have learned to regard the influence of the external conditions on the growth of a living animal or plant (in this case the tree) as a most profound one; in fact, this influence seems to determine, with plants even more than with animals, the size and form and vigor of any or all parts. It is probably owing to the different conditions under which different trees grow that such variable wood is formed. The differences in the wood are largely in the size of the wood cells, the thickness of their walls, and the extent of infiltration of these walls in the heartwood. This variability extends to the natural resisting power of the timber to decay. Some oak ties decay in three years, while others cut and laid at the same time last ten to fifteen years. It is well to bear in mind that the time of cutting and the subsequent care given to cut timber may have something to do with its behavior when it comes to the impregnating stage.

SUMMARY.

The facts set forth in the foregoing may be summed up as follows: Wood is composed of many tubes, having a complicated structure. These tubes are invaded by low plants, called fungi, which bring about changes in the fibers, which changes are called decay. There is a marked difference in heart and sap wood, and in different woods, with reference to their susceptibility to decay.

TIMBER PRESERVATION.

INTRODUCTION.

The first attempts made to preserve timber from decay date back many centuries, when wood was charred to make it more resistant. Later on came a period when wood was coated with preservative paints, and then attempts were made to inject preservatives into the wood. The literature dealing with this subject is bewildering, for as soon as the prices of timber began to rise, owing to scarcity of material, all sorts of processes were devised to increase the life of the wood.

It is not the present intention to add to this already voluminous literature, and anyone who is interested in the historical development of this question is referred to the works of Paulet, Bruesch, Boulton, Chanute, Curtis and others, likewise to Bulletins 1, 3, and 9,

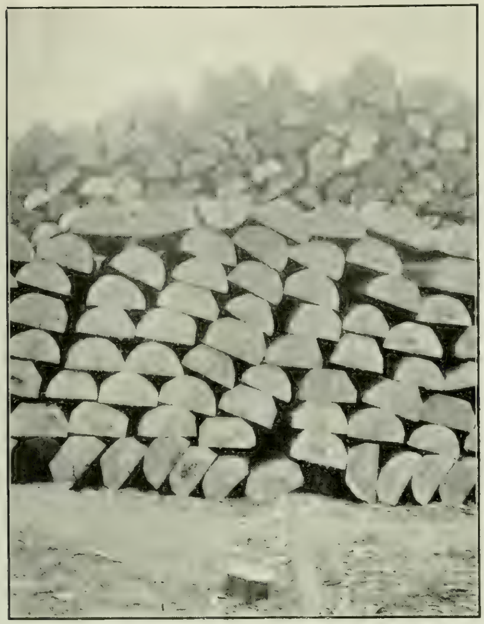


Fig 1.—Pile of new Oak Ties at Ghent, Belgium. (Note "S" in Ends.)

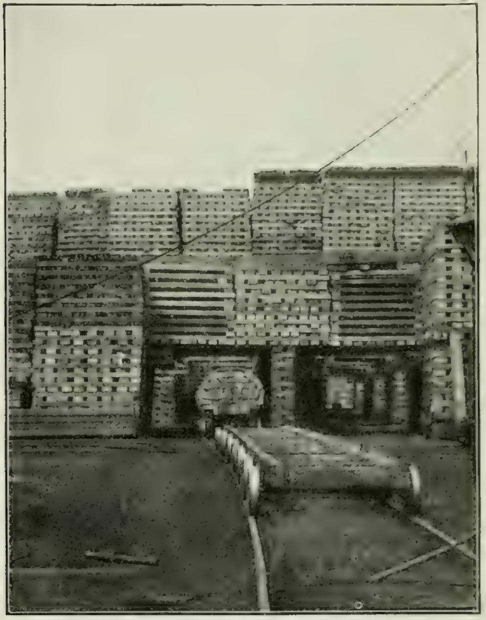


Fig. 2.—Scotch Pine Ties Seasoning, Great Western Railway, England.

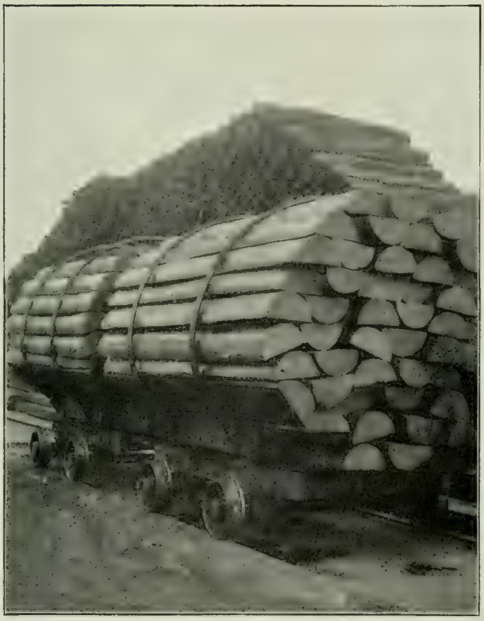


Fig. 3.—Oak Ties Ready to Enter Cylinder, Ghent, Belgium.

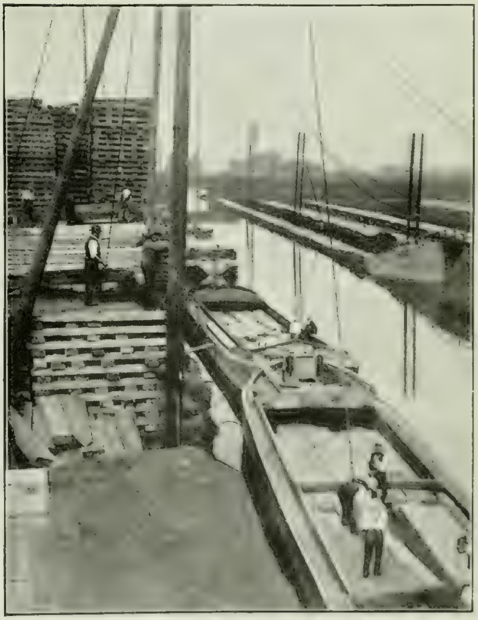
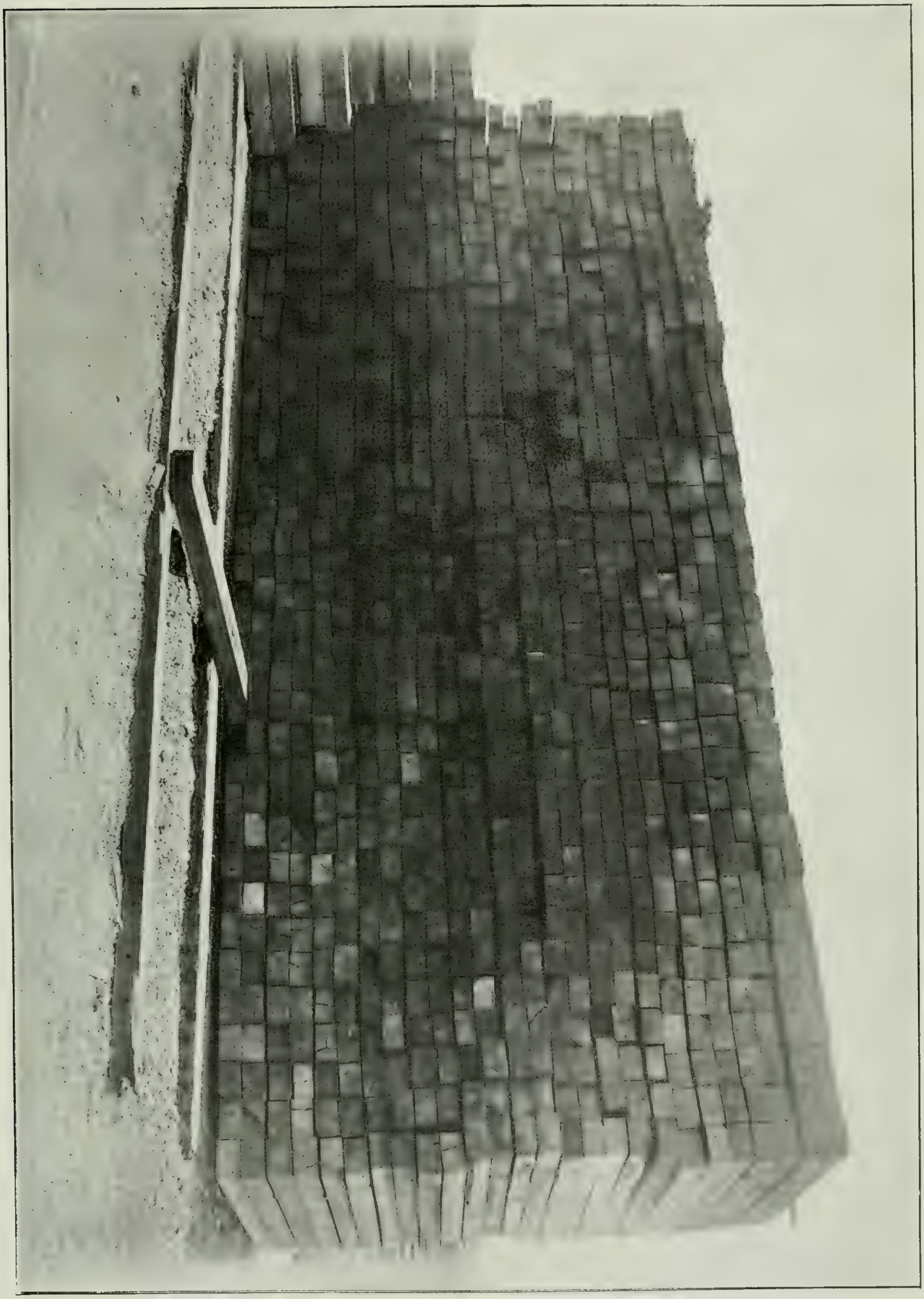


Fig. 4.—Ties Arriving in Canal Boats Great Western Railway England.



AMERICAN TIMBER RECENTLY CUT, SHOWING POOR METHOD OF PILING.

Forestry Division, United States Department of Agriculture, mentioned in the annexed bibliography. Suffice it to say that the processes advocated consisted in either external applications of preservatives or in forcing the preservatives into the wood. The trials were attended with varying degrees of success, and of the large number advocated (Paulet mentions 174 in all) only a few have survived. The painting processes, for wet exposures, have gradually fallen into disuse, because it was found that by covering the outside of a timber with an impervious coating the evaporation of water was prevented. This gave any chance fungus spore, which may have been on the wood before coating, an opportunity for rapid growth, thus destroying the wood rapidly. Some of these processes are still being advocated, but it is hardly necessary to say that in most cases they do more harm than good.

The processes which depended upon getting preservatives into timber encountered from the first great difficulties because of the peculiar structure of wood. It was not realized, and it is not realized by many even at this day, that the wood fibers are not like so many open pipes. The sapwood is more easily injected and absorbs more preservative because it allows of a greater water penetration than the heartwood, where cell walls are made more or less impermeable because of the wall infiltrations. Pressure was resorted to to drive the solutions employed into the wood. These solutions were usually heated, in order to increase the amount pressed in, as hot solutions penetrate porous matter more readily than cold material. The materials used for impregnation differed. They were and now are chiefly copper sulphate ($CuSO_4$), zinc sulphate ($ZnSO_4$), zinc chloride ($ZnCl_2$), mercuric chloride ($HgCl_2$), aluminum sulphate ($Al_2(SO_4)_3$), and the products of coal-tar distillation. The various methods now in use will be referred to below.

THEORY OF IMPREGNATION.

The theory upon which the injection of salts into wood is based is that the salts act as poisons, killing the fungi or bacteria which grow in wood and destroy it. The amount of salt of one kind or another necessary to kill the fungi varies, but is usually very small. In order to protect the wood it is necessary to have a certain amount of salt so distributed that it will suffice to prevent the growth of the destroying agents. As soon as the amount of salt present falls below that definite quantity, growth of the fungi will be possible. Most of the salts injected are soluble in water. The solutions are made of varying strength, but usually very much stronger than is necessary to prevent growth of the fungi, for a simple reason. Timber impregnated with a salt soluble in water will have part of that salt removed every time the timber comes into contact with water. The object of preservative processes of to-day is therefore to inject as much salt as will go in, so that the time in which all the salt will be leached out may be made as long as possible. Experience has given us a long series of figures as to the amounts of salts of various kinds injected into various timbers necessary to insure their lasting for some time. These figures vary considerably, as was to have been expected. The reader is referred to extensive reports on this subject by Chanute, Curtis and others.

One must not forget that it is the presence of the injected salt which prevents decay. A piece of wood may be in a locality excessively favorable to the growth of fungi, but as long as the amount of salt necessary to destroy the fungus is present, just so long will the wood remain sound. It is of no use, therefore, to accelerate the growth of fungi in newly injected wood, as has been suggested, in order to test the efficiency of a preservative. Only when the amount of salt in the wood is decreased below a certain per cent can the fungus begin to grow.

Theoretically, in order to obtain perfect protection, the preservative ought to penetrate every part of the wood. With the impregnating methods which depend on pressure this is practically impossible, because of the structure of wood, as already pointed out.

To sum up, an ideal preservative ought to conform to the following conditions:

(1) It must be poisonous to bacterial and other destroying agents.

(2) It must be capable of easy injection, and when once in the wood it ought to stay there.

(3) It must penetrate all parts of a piece of timber; to which a fourth condition must be added because of present economic conditions.

(4) It must be cheap.

RETROGRESSIVE CHANGES WHICH TAKE PLACE IN IMPREGNATED WOOD.

Wood impregnated with salts soluble in water undergoes changes as soon as it is exposed to weathering influences. The rate with which the injected salts are leached out differs with the timber. In general, they leach out most rapidly from those timbers into which they were injected with the greatest ease. The leaching out is, however, dependent on several circumstances. If wood be placed in a position where it comes into contact with water immediately after or shortly after impregnation, contact will be established between the solution in the wood and the water outside, and a rapid transfer of salt will result. In wood which has been dried after impregnation the water from without must first of all force an entrance into the dry wood, which is a slow process. In the dry wood impregnated with zinc or copper salts, for instance, these salts are deposited in the lumen of the wood fibers as the water evaporates. The greater portion of the lumen is filled with air, which makes the entrance of water from without an exceedingly slow process. It follows from this that impregnated wood (i. e., impregnated with a water solution) will retain its antiseptic salts much longer when placed under conditions unfavorable to lasting, if such wood has been thoroughly dried after the impregnation. As this is a point of considerable economic importance, reference will be made to it later.

The changes which wood impregnated with substances insoluble in water undergoes are as yet little known. Wood impregnated with products of coal-tar distillation may lose some of these products by evaporation. Many of the coal-tar derivatives are slowly volatilized at temperatures reached during the summer. In cases where light oils have been used all of these may disappear in the course of a few years. As noted by the writer some years ago, this was the case in some timbers impregnated with creosote and laid in the hot sands of New Jersey. When impregnated with products which do not boil below 175° C., wood may last almost forever, at least without decaying.[a] (See Pl. XIII, fig. 3, representing a post of Baltic pine (*Pinus sylvestris*) impregnated forty years ago.) In moist tropical countries the changes in wood treated with coal-tar derivatives are different from those in temperate climates. The writer is informed that the creosoted sleepers on the Chilean State railways last but a short time in the moist, warm forests of that country; but then, again, the excellent results obtained on the Indian railways with Baltic pine sleepers impregnated with creosote point to the fact that even under the most severe conditions, when properly treated with proper oils, the coal-tar products remain in the wood. The poor results obtained in Chile, Spain, and Portugal with creosoted timbers are probably to be explained by the fact that inferior work was done for the sake of cheapening the process. As will be pointed out below, it is a rather suggestive fact that wherever poor results were obtained with tar-oil impregnation there the cost of the process is also very low. (See the tables given by Herzenstein.)

The changes which other insoluble salts (see below) undergo are not yet known, because the processes using these salts are of too recent development.

It may be stated again at this time that as soon as the preservatives disappear from the wood the decay can begin.

RESULTS OF TIMBER IMPREGNATION.

INTRODUCTION.

Timber impregnation has been carried on for so long that there has been ample time to secure some results. The decay of ship timbers aroused the inventive spirit of the British at the beginning of the eighteenth century, but it was not until the general use of timber for railway ties began that much attention was paid to the treatment of timber. Boulton[a] states that "by the year 1838 four several systems of antiseptic treatment were fairly before the public and competing for the favor of engineers. These were corrosive sublimate, sulphate of copper, chloride of zinc, and heavy oil of tar." Since that time these four processes have been tried with varying success in many climates and countries. The impregnation was carried on by railway companies in particular, for they used the larger proportion of that timber supply which was placed under conditions favorable to decay. Experiments of various kinds were conducted, generally by separate companies, by engineers, or scientific bodies. These experiments, and the experience of railway engineers and others, have shown beyond question that there are certain salts which, when injected into timber, will prevent decay, and by so doing increase the length of life of the timber. It may be said with safety that the four processes referred to by Boulton all prevent decay of timber more or less. It is, then, no longer a question whether decay can be prevented, or, to put it otherwise, whether an increased length of life can be obtained for any given kind of wood; nor is it a question whether it is possible to do this economically, i. e., whether it will pay under the conditions which obtain in the different parts of the United States to-day. There can be no doubt that there are processes which do increase the length of life of timber, and do so at a reasonable cost. The question which is before those who use timber for any structural purpose is: Which one of the numerous processes advocated shall we use? This applies to railroad ties, fence posts, bridge timbers, telegraph and telephone poles, and in fact structural timber of all kinds. The answer to this question must take into consideration (1) the cost of the operation; (2) the comparative efficiency of the various treatments; (3) the readiness and ease with which any one treatment can be employed. The answer must be no uncertain one. A decision one way or the other will involve a considerable outlay of capital, the returns from which will not be evident or even certain for many years. While the results obtained during the last forty years are beyond question of great value as indicating the extent to which one or another process may be trusted, we have few indications as to the comparative value of these various processes. The results were obtained in particular sections of country; they are restricted to particular soil conditions of which we have only scant records, and to particular kinds of timber. While it is without doubt true that all timbers when placed under the same conditions will decay, and will probably behave in a similar manner when injected with any salt, there will be differences in the length of time which they will resist—a most important factor from the economic standpoint.

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[a] Throughout this report mechanical destruction will be expressly mentioned; in all other cases decay by fungi will be understood.

Anyone who has gone over the published statements of results of timber treatment can not but be struck by the numerous contradictory statements found in these reports. Voluminous discussions upon this question have appeared every year, and yet there seems to be no well-defined understanding of the best method of timber treatment. The difficulty has been that many have tried to compare results obtained with the same or similar processes in different localities under different conditions. It is obviously unfair to condemn a process because it has given poorer results in Georgia than in a Northern State, if the work has been done equally well, and to draw the conclusion that it will prove disappointing on that account in the Northern States. The trials given any one process have been made with different timbers, and oftentimes while using the same salts different methods of impregnation have been employed. One may be warranted in stating that it may prove economic to employ one system in one place, another in a second part of the country. Discussions of results obtained in that way have little value and tend to confusion and cloudy conceptions. One must face the problem squarely, and experiment with a definite end in view. The absolute value of an impregnating method in terms of years will probably never be known because of the variability in conditions, but one can obtain results as to the comparative value of the different methods.

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[a] Boulton. The Antiseptic Treatment of Timber, p. 9.

In a following chapter an experiment will be described, which was begun this year, with the intention of getting at some of the data spoken of above. Similar experiments have been made on some of the European lines, but these have been for the most part (with one exception) conducted by many people and with variable conditions, so that the results obtained are questionable. Reference need only be made to the results obtained on one of the Austrian roads, the record of which is given on Diagram I. (See also p. 46.)

EXPERIMENT MADE IN TEXAS.

The chief difficulty encountered in obtaining results with any one method of timber treatment is, as has been pointed out, that one must wait for such a long number of years before arriving at satisfactory conclusions. It is well known that treated timbers decay with greater rapidity in some parts of this country than in other parts. It was thought possible that, by selecting a region where decay took place with the greatest rapidity, the retrogressive changes which take place in timber might be hastened. After an inspection of different sections, the southern part of Texas was selected as fulfilling the desirable conditions. The ties treated with chloride of zinc had decayed in from two to four years in this section, while untreated timber decayed in twelve to fourteen months. A portion of track belonging to the Santa Fe Railroad was selected, lying some 75 miles east of Somerville, Tex. The ground in which the timber is placed admits of little drainage. The annual rainfall and the average temperature are high. The track is shaded for some distance. These conditions favor not only rapid changes in the salts injected into timber, but also rapid growth of the destructive fungi when once the amount of salt injected has fallen below the minimum. The experiment was begun with ties, for the reasons mentioned in the introduction, that they offer the best means of obtaining rapid results.

The plan of the experiment was as follows. It was outlined with a view of answering these questions: (1) Which treatment now advocated gives the best results (under the same conditions) in increasing the length of life of the timber? (2) Does one and the same kind of treatment give the same results with different timber? (3) Can inferior timbers be made to pay for the cost of renewal by impregnating them with one salt or another?

It was fully realized that practical results could be obtained only under actual conditions. Laboratory experiments are valuable as indicating what may be expected, but they rarely are borne out absolutely in practice. The timbers used were donated by various railroad companies. Owing to this fact a certain amount of experimental freedom had to be sacrificed. It would have been desirable to use a much larger number of ties and also several other kinds of wood. The experiment is, therefore, to be regarded as a first step, which will have to be improved upon as rapidly as it may be possible. Too much emphasis can not be laid upon this test, which, if conducted properly, can be made to answer most of the unsolved questions now awaiting answers.

The following timbers were used, their sources being given as nearly as it was possible to learn them. After each kind of timber the mark assigned to each in the record nails is indicated:

White oak	W
Red oak	RO
Black oak	BO
Spanish oak	SO
Willow oak	WO
Beech	B
Hemlock	H
Tamarack	T
Long-leaf pine	L
Short-leaf pine	S
Loblolly pine	LL
Red-heart pine	RH

The table following shows the number of ties used and the treatments given each. The treatment was carried out by the representatives of the various companies now doing business in this country. The ties were dried several months before laying, and were then placed in the track. Each tie is marked with three nails. These nails are of heavy wire, coated with zinc. In the head the letters or marks were stamped. Each tie has nails showing the date, the kind of timber, and kind of treatment. The nails were placed about 4 inches outside the rail.[a] Accurate records will be kept by this Department, and reports will be issued from time to time, showing what progress is being made.

While this experiment will without doubt yield some valuable results, the writer can not refrain from adding that it could be very much improved upon. The circumstances under which the experiment was made were of such a nature that many of the factors involved could not be controlled. The ties were donated by various railway companies. They were cut at different seasons and in different sections of the country. They were seasoned different lengths of time before treatment and, owing to delays in shipment, for different periods after treatment. Then, again, there ought to have been many more ties of each kind, to do away with the variability of individual ties. In spite of these defects, the experiment is a beginning in the right direction. As pointed out in the conclusion, every railroad which does any treating ought to consider its treating as part of a large series of tests. These might be watched, and the results correlated by the Government. It is only when this work is done on a large scale that absolutely trustworthy records will be obtained.

Besides the experiment in Texas, an experimental greenhouse and culture pit was constructed at St. Louis for the purpose of investigating the comparative rate of decay of different timbers. Pieces of wood, one half treated, the other half untreated, are inoculated with destructive fungi and are placed under the most favorable conditions for rapid decay. It is too early as yet to give any results.

TABLE I.—*Variety and number of railroad ties laid on Atchison, Topeka and Santa Fe Railroad and the kind of preservative treatment each received.*

NOVEMBER 20, 1901.

Process.	Rock Island Railroad.	Atchison, Topeka and Santa Fe Railroad.					Pennsylvania Railroad.	
	Hemlock. H.	Long leaf pine. L.	Short leaf pine. S.	Lob-lolly pine. LL.	Red heart. RH.	Red oak. RO.	Beech. B.	Black oak. BO.
Burnett. Zinc chloride. BU	100	100	100	100	--------	100	100	100
Wellhouse. Zinc tannin. WE	100	100	100	100	--------	--------	100	100
Alderdyce. Zinc creosote. AL	50	50	50	50	--------	--------	50	50
Alderdyce. Zinc creosote, English oil. AL**	50	50	50	50	--------	--------	50	50
Barschall. BA	100	100	100	100	100	100	100	100
Beaumont oil	--------	100	--------	100	--------	--------	--------	--------
Zinc chloride, Beaumont oil. BZ	--------	100	--------	100	--------	50	--------	--------
Spiritine. SP	--------	100	--------	100	--------	--------	--------	--------
Untreated	100	100	100	100	--------	--------	100	100

---

[a] The nails had to be placed outside because the middle of the ties was completely covered with ballast.

TABLE I.—*Variety and number of railroad ties laid on Atchison, Topeka and Santa Fe Railroad, etc.*—Continued.

NOVEMBER 20, 1901—Continued.

Process.	Messrs. Wm Ripley & Son.	Missouri Pacific Railroad.	Cotton Belt Railroad.	Illinois Central Railroad.	Ayer & Lord Tie Company.				
	Tamarack. T.	White oak. W			Red oak. RO.	Black oak. BO.	Turkey oak. YB.	Spanish oak. SO.	Willow oak. WO.
Burnett. Zinc chloride. BU	50	100	--------	100	20	20	20	20	20
Wellhouse. Zinc tannin. WE	100	100	--------	100	20	20	20	20	20
Alderdyce. Zinc creosote. AL	50	--------	50	50	10	10	10	10	10
Alderdyce. Zinc creosote, English oil. AL**	50	--------	50	50	10	10	10	10	10
Barschall. BA	100	--------	100	100	20	20	20	20	20
Untreated	50	--------	100	100	20	20	20	20	20

RESULTS OF TIMBER IMPREGNATION IN EUROPE.

For many years experiments and practical tests have been made in Europe to determine the value of preservative processes. Reports concerning results have from time to time appeared, notably that of Flad and recently that of Mr. O. Chanute. In the present account much that these writers mentioned is verified, and here and there quotations from the earlier reports are given.

During the past summer the writer visited various European countries, including England, Belgium, Germany, Switzerland, Italy, Austria, Russia, and France, for the purpose of making a personal investigation of the results of timber impregnation, as obtained by railroad companies and others interested in the impregnation of timber. During the entire trip attention was paid in particular to the increased length of life which various methods of treatment gave to timber, as shown by the actual position in service of railway ties, telegraph poles, mine timbers, etc.; furthermore, to all those attendant factors which influence the life of structural timber, such as the condition of the soil in which timber is placed, the drying before and after treatment, the shape of timbers, the relation of heart and sap wood, etc.

In the following pages the results of the observations will be given in brief, to be followed by general considerations. Before giving the writer's personal observations, attention is called to the report published under the direction of M. Vladimir Herzenstein, of St. Petersburg, by the Sixth International Railway Congress, entitled Question VIII—The Preservation of Timber, Paris, 1900. In this report the answers sent in by 87 railways, of these 79 European, to the 74 ques-

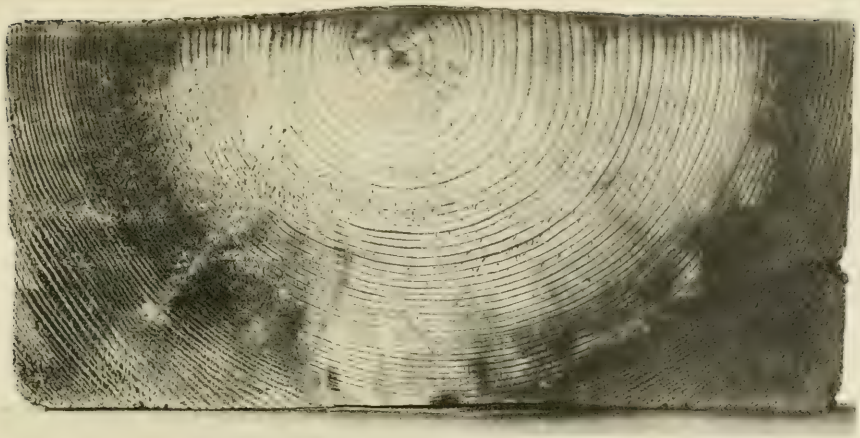

Fig. 1. Median section of new Baltic pine tie (England), impregnated with tar oil.

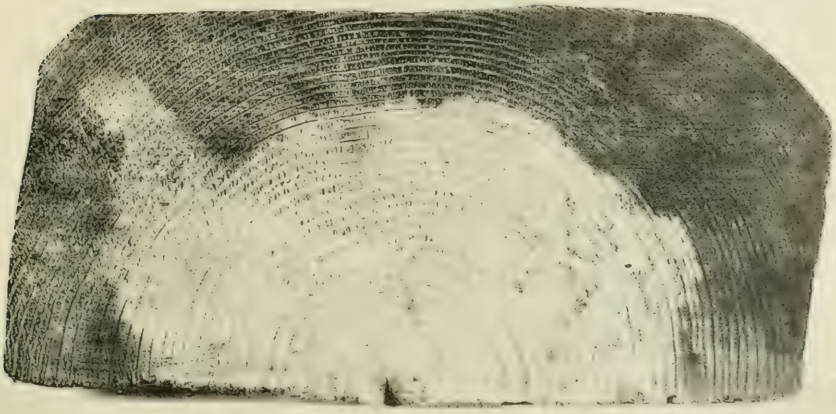

Fig. 2. Median section of Baltic pine tie after 16 years service, impregnated with tar oil.

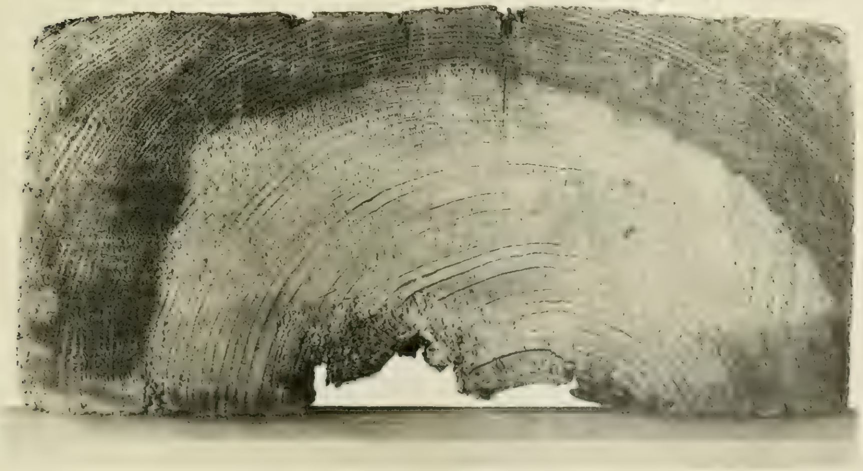

Fig. 3. Median section of Baltic pine tie, impregnated with tar oil, showing how decay starts.
(This tie is still good for several years.)

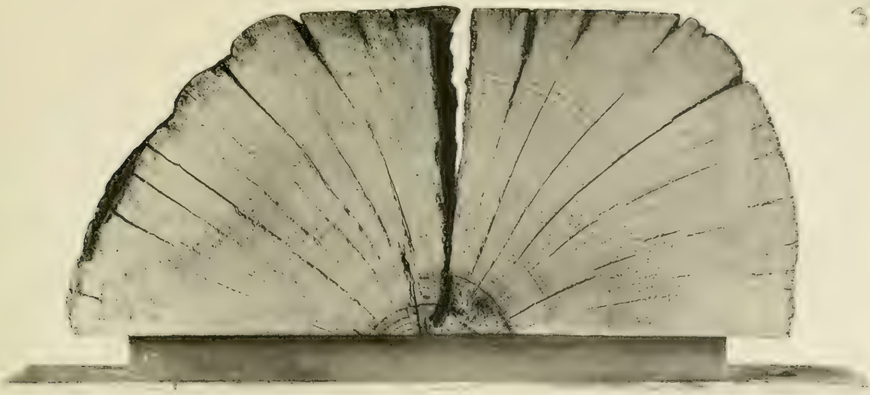

Fig. 1. Median section of beech tie (France), impregnated with tar oil; laid in track in 1869.

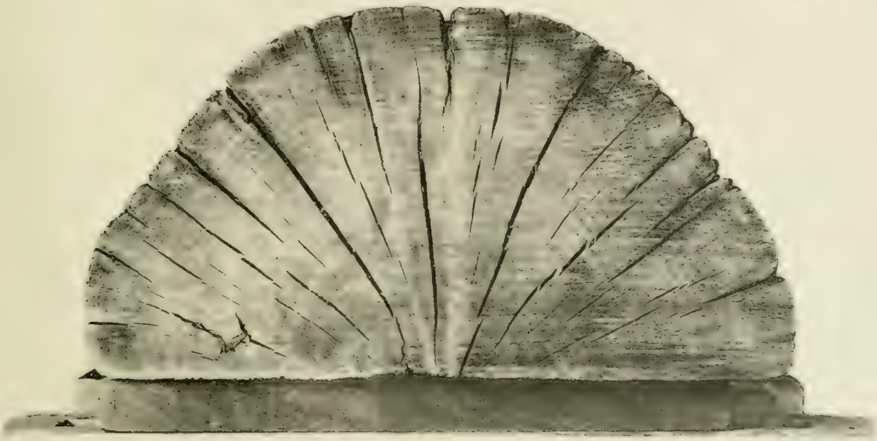

Fig. 2. Median section of beech tie (France), impregnated with tar oil; laid in track in 1870.

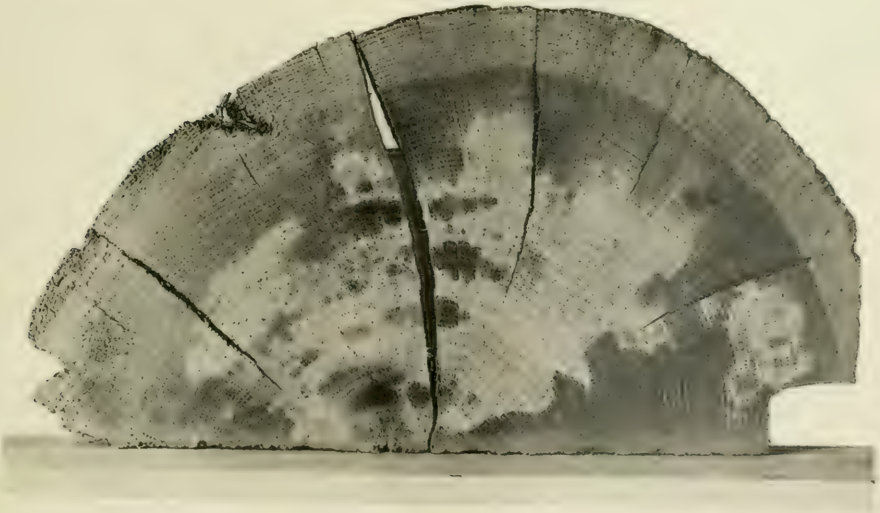

Fig. 3. End section of freshly impregnated oak tie (Belgium), using tar oil.

tions of the commission are tabulated, preceded by a brief statement by the author. The following passages are quoted from the English translation of this report, and will serve to show, better than any long discussion, the present situation of the timber-impregnation question in Europe. Under the heading of "Wood for all structural purposes" we read, page 8: "As far as the substances which are used by the different managements to prevent decay and to produce non-inflammability are concerned, we have to report that the majority of the managements do not pay much attention to this subject." Page 11: "The data we have received on the properties of pickled and unpickled wood are not very comparable, as the respective conditions are very different." Conclusions: "1. The chief defect of unpickled wood for structural purposes is that it is liable to rot. 2. Creosoting puts off such decay for a long time," etc.

Under the heading "Railway Sleepers" we read, page 20: "Unfortunately we are obliged to report that no special progress has been made in preservative processes, although any improvements in them would lead to considerable economy in the maintenance of railways. * * * The different managements have supplied us with much information as to the age of the wood, but without giving us any information on the influence which the age of the wood has on its life and on the efficacy of the pickling processes." Page 22: "The information we have received does not enable us to determine to what extent the life of sleepers is affected by the interval of time between the time the timber is felled and the time when it is cut up into sleepers."

These extracts might be carried on to great length, but they will suffice to show that some of the most vital points connected with timber impregnation are as yet unanswered. M. Herzenstein has put together an immense array of facts, but they are open to the objecion that they are very incomplete because of the failure on the part of the railway companies to answer the questions put to them. The report ought to be carefully digested, for in its present condition one must hunt laboriously through long columns of figures, which is very unsatisfactory.

In the following the writer's observations will be grouped under the following headings:

Ties, poles, etc.
Ballast.
Tie plates.
Impregnation.
Life of ties.
Removal and disposal of ties.

TIES, POLES, ETC.

KINDS OF TIMBER.

The ties in use on European railroads consist mainly of Scotch pine (*Pinus sylvestris*), oak (*Quercus robur pedunculata*), and beech (*Fagus sylvatica*). In England the Australian woods karri (*Eucalyptus diversicolor*) and jarrah (*Eucalyptus marginata*) are being employed to some extent. Chilean quebracho has been tried in France. The ties are cut at different seasons of the year, generally in the fall or winter, and shipped, generally by water, to some receiving point, where they are inspected. The cost of ties varies considably, as may be observed from the appended table. A great deal of attention is devoted to the classification of ties. Exact specifications are drawn up in most countries, giving exact dimensions, terms of delivery, etc. Some of these are given in Appendix I. The terms of these specifications are rigidly adhered to. At every receiving point a corps of inspectors makes examination of the incoming ties, rejecting all those which do not come up to the established standard.

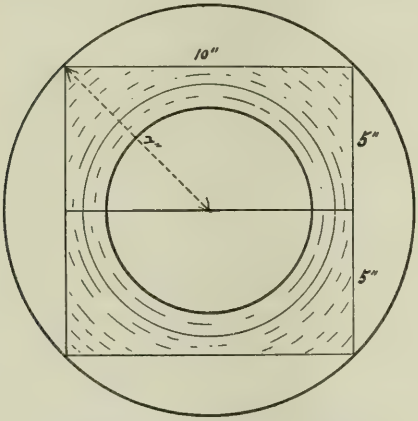

FIG. 13.—English system of cutting ties, tree 14 inches diameter (Baltic pine).

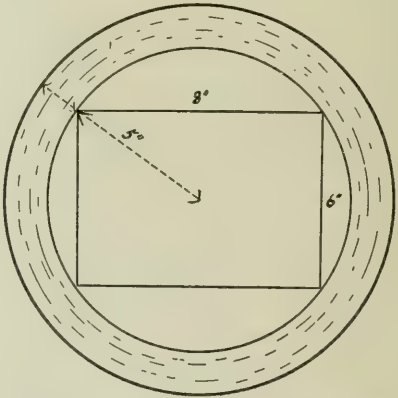

FIG. 14.—Extreme form of present American system of cutting ties; a "pole tie" of oak.

FORM.

On Plate XII are given the forms of cross sections as adopted on some lines. It will be noted that there is a good deal of diversity of form, brought about no doubt by strict adherence to long-established customs. Attention is called in particular to the form of the English tie and the half-round form commonly found in Belgium. The English ties are cut two from a log; the latter is sawn to form a square timber 10 by 10 inches. In this form it is delivered to the railroad, and is then sawn in two, making two ties, each 5 by 10 inches (see fig. 13). The Great Western Railway specifies particularly that the ties shall be delivered in the form of logs 10 by 10 inches. These ties consist of a large portion of sapwood, surrounding the heartwood on all sides but one. The ties after being creosoted are laid with the heartwood side down, as represented in the accompanying plate (Pl. X, fig. 1). The more resistant wood is thus brought into contact with whatever moisture there may be in the soil. This fact will be referred to at another place. The Belgian tie is of similar character, with this difference, that it is left half round. Its flat heartwood side is laid downward. Deep cuts are made into the rounded side to give a flat base for the rail. The specifications for all European ties include clauses excluding decayed or injured timber.

TIE SPECIFICATIONS.

The high price of timber has led to the adoption of specifications for ties on the European roads which allow of the greatest possible utilization of material from one tree. England and Belgium lead in that respect, since they get two ties from a log from which, as a rule, but one would be obtained in this country. This is made possible only because they make use of all the sapwood, and make this last as long as the heartwood by impregnating it. Any consideration of their way of cutting ties must take this into account. One must remember, furthermore, that sawed timber is used in all cases.

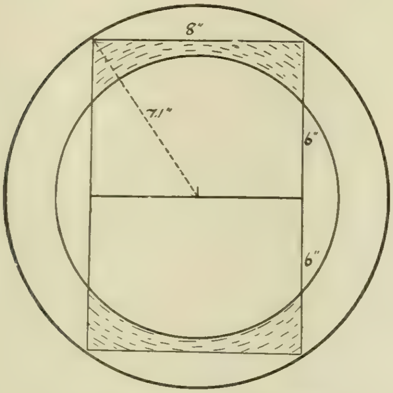

FIG. 15.—Proposed system of cutting ties (oak).

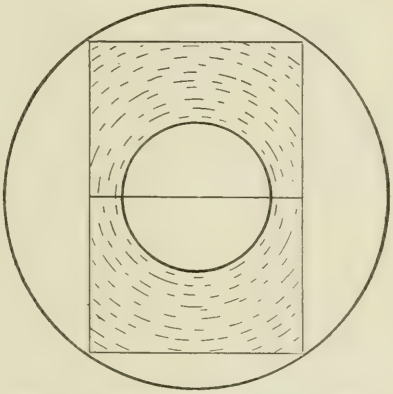

FIG. 16,—Proposed system of cutting ties (loblolly pine).

Figure 13 shows a log of Baltic pine, and illustrates the manner in which the English lines cut two ties from a tree. Figure 14 shows an extreme case of the present method of cutting a tie from a small tree, i. e. a tree which would make but one heartwood tie. The dimensions given are taken for the sake of illustration, and need not be considered final.

As the more economic use of timber is one of the problems which will engage active attention in the future, the writer ventures to suggest the possibility of imitating the method of tie cutting as practiced in England, with some modifications, chiefly of size. This will refer only to treated timber. It may not be practicable to do this in all parts of the United States, but it is a point which is worthy of consideration and discussion.

Figures 15 and 16 show how two ties could be cut from a tree,

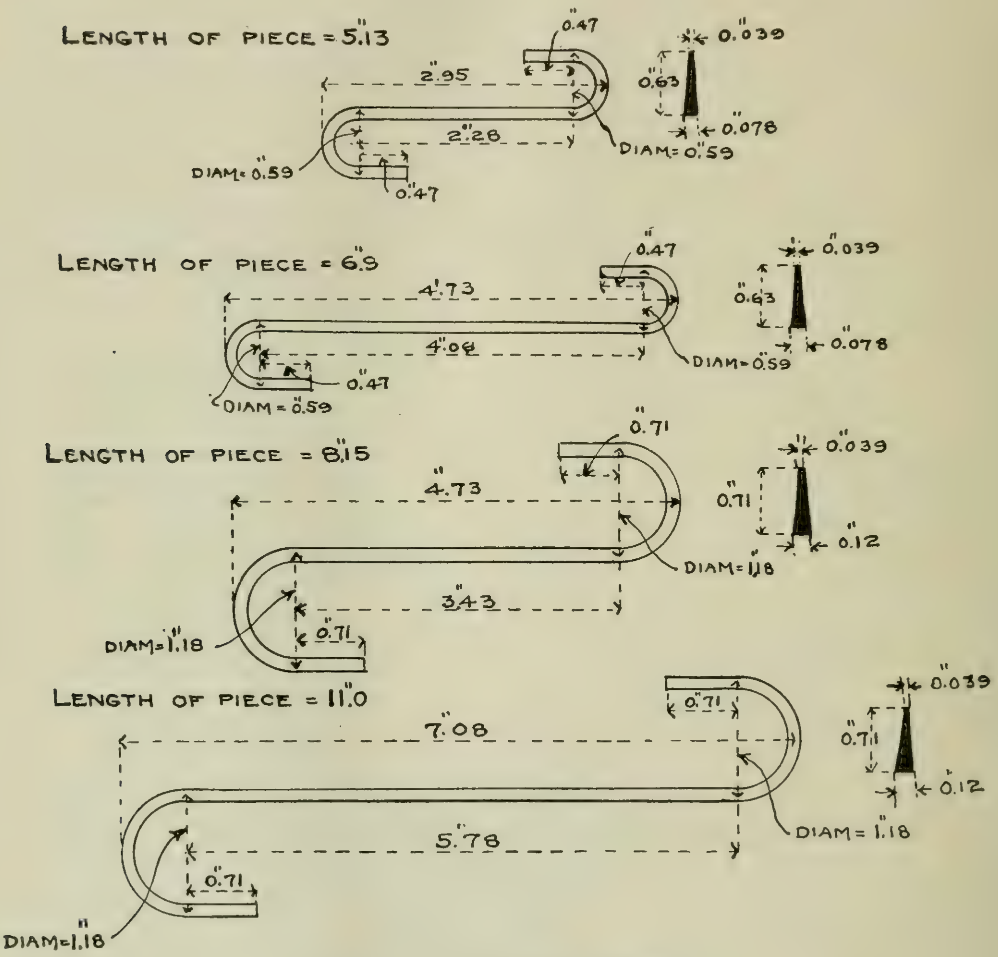
LENGTH OF PIECE = 5.13"
0.47"
0.039"
2.95"
0.63"
2.28"
0.078"
DIAM = 0.59"
DIAM = 0.59"
0.47"
LENGTH OF PIECE = 6.9"
0.47"
0.039"
4.73"
0.63"
4.08"
0.078"
DIAM = 0.59"
0.47"
DIAM = 0.59"
0.71"
LENGTH OF PIECE = 8.15"
0.039"
4.73"
0.71"
0.12"
DIAM = 1.18"
3.43"
DIAM = 1.18"
0.71"
LENGTH OF PIECE = 11.0"
0.039"
0.71"
7.08"
0.71"
0.12"
DIAM = 1.18"
5.78"
0.71"
DIAM = 1.18"

FIG. 17.—"S" used to prevent checking.

assuming that the present depth be sufficient. The new method would mean a wider tie, and one which would require more care in laying, as the heartwood side would have to be at the bottom. This would be no objection, for when ties are treated they become objects worthy of more care than is now given to untreated timbers. The writer believes that a section man could be taught to lay a tie properly, despite the objections made by some engineers and superintendents. Our workmen are surely as intelligent as those on the European roads, and if properly directed there is no reason why the same care in laying ties can not be obtained here as abroad.

Ties cut two from a log would be somewhat less expensive; they would all have approximately the same form, which would be of great value in impregnating. An experiment will be tried during the coming year with ties cut in this manner, to determine exactly what may be expected of such a system.

SPLITTING.

Various devices are employed to prevent wood from severe checking and cracking. Many roads employ S-shaped steel bands, which are driven into the ends of badly cracked ties at right angles to the crack, thus preventing any further splitting (fig. 17). On some of the French lines bolts are inserted through the end to hold badly split beech ties. Various forms of wooden pegs are also used on some roads.

STACKING.

In all countries the ties are stacked and dried before being treated. The time varies considerably in the different countries, but is never less than four to six months. In some cases it is dependent upon the demand for ties. At the impregnating plant of the Great Western Railway in England the ties are allowed to season for six months before treatment with creosote. The Eastern Railway of France allows fifteen to twenty months for oak and six months for beech. The European engineers have found out by long experience that it is absolutely essential that the ties be thoroughly dried before submitting them to any one of the different treatments. A great deal of care is taken in

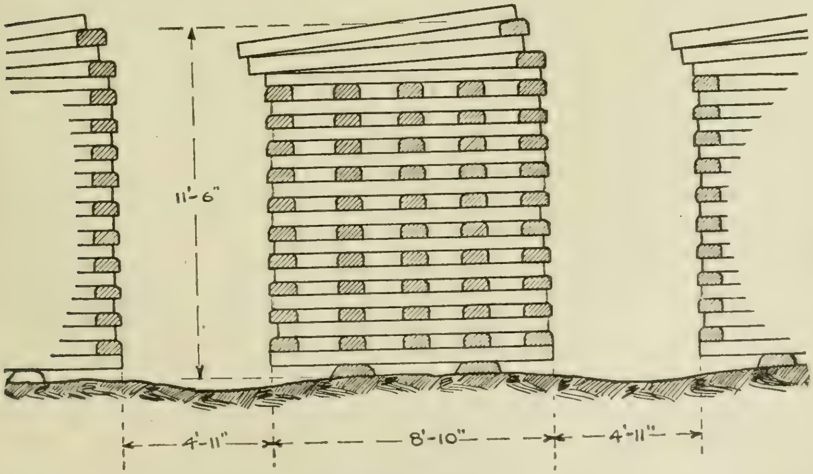

FIG. 18.—Pile of ties on French Eastern Railway.

piling the ties, so that their greatest amount of surface may be exposed to the sun. The Eastern Railway of France has probably brought the piling methods to the highest state of perfection. They build the piles, as shown in the annexed diagram (fig. 18).[a]

The slanting ties at the top are so arranged that the rain water runs off almost wholly. Before treatment (in all countries) the ties are prepared in various ways to give the proper slant to the rails. In some cases holes are bored for the screw spikes or treenails, and those which are to receive chairs are adzed. Wherever a water impregnation is used the treated ties are stacked for two months or more after treatment in order to have as much of the water as possible evaporate before laying the tie in the roadbed.

SUMMARY.

How far the rigid requirements of the European roads can be followed here is questionable. Tie inspection is now carried on in this country after a fashion. Some attention is paid to defects and to small ties. It is probably not desirable to make the specifications for ties as stringent as abroad, because ties are cut with us from trees of all sizes. The tie supply of most European roads is determined by the forestry regulations. In their forests trees of uniform size are cut, and it is therefore easy to obtain thousands of ties which conform accurately to a prescribed size. This would be almost impossible under our present conditions for the reason stated, and the advantage would hardly be great enough to warrant taking so much trouble. Defective ties can and ought to be inspected against rigidly, as such ties will create trouble when impregnated and afterwards.

The long seasoning before treatment, almost universally practiced abroad, is one of the greatest factors leading to successful impregnation with methods employing pressure. Its value can hardly be questioned. The seasoning after treatment is fully as important, and perhaps more so. This is a feature not sufficiently attended to in this country, and yet it is almost as vital as the impregnating itself. During this seasoning process the water or volatile substances in the wood are given an opportunity to leave the wood under the most favorable circumstances. When once placed in the soil in contact with moisture, the water in the wood has no opportunity of evaporating. In the case of a soluble salt, this leaches out with the greatest rapidity from wet wood, while dry wood is penetrated more slowly by water, and consequently lasts longer. The same is true of a process such as the Hasselmann treatment, where it appears to be necessary to dry the wood in order to render the union between the cellulose wall and the impregnated salt more certain.

The drying of ties before laying might be attended to with excellent results in this country, where no subsequent treatment is given to the timber. A tie laid into the track while still full of water will decay very rapidly. The extra care used in piling ties so as to leave sufficient air space between ties would be amply repaid by the longer service which would be obtained from such seasoned ties.

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[a] Dufaux. Note sur la preparation des traverses, p. 11.

The methods of preventing splitting by means of S has been referred to.

BALLAST.

The ballasting of most roads is attended to abroad with extreme care. On Plates XV-XVIII are shown sections of roadbeds in England, France, and Germany. It will be noted that in most cases the depth of ballast under the ties is considerable. The base line upon which the ballast rests is usually arranged so as to allow any water to run into a lateral ditch. The material of which the ballast is composed varies as much as in the United States, preference being given to broken stone or pebbles wherever possible. The ties are usually covered with the ballast. This would seem to increase the danger as far as decay is concerned, but with good drainage this is counterbalanced many times by the increased stability obtained for the whole roadbed.

TIE PLATES.

Tie plates are used universally. Where chairs are employed to hold the rails, the base of the chair acts as a tie plate. The writer was informed that on some of the English roads it was due largely to the increase in the base area of the chairs that the recent long increase in the lasting powers of Baltic pine ties was obtained. In Germany the tie plates are flat steel plates, considerably larger than the base of the rail. The most remarkable results of all those seen were obtained in France on the Eastern Railway. This company has for many years used tie plates of felt about one-fourth inch thick. Of late it has employed plates made of poplar wood one-eighth inch in thickness. These pieces are impregnated with creosote and laid in the adzed part of the tie. The wear which usually goes to disintegrate the wood of the tie is there taken up by the poplar, which is renewed at short intervals. The cost of these plates is given at $3 per thousand.

There can be no question that the increase of the bearing surface has added materially to the length of life of most European ties and that it would do so to a marked extent to our ties. It is hardly fair to apply European standards to the conditions obtaining in this country. The utility of the tie plate depends so much on the weight of the rolling stock and the speed of trains that a conclusion as to the value of any one form ought to be drawn solely from experience here. For soft woods a broader bearing surface than that of the rail will prevent the rapid cutting in of the fiber. It remains to be seen how far the cutting of the fiber by flanges or spines, intended to anchor the plate in the timber, counterbalances the saving of rail cutting.

FASTENING.

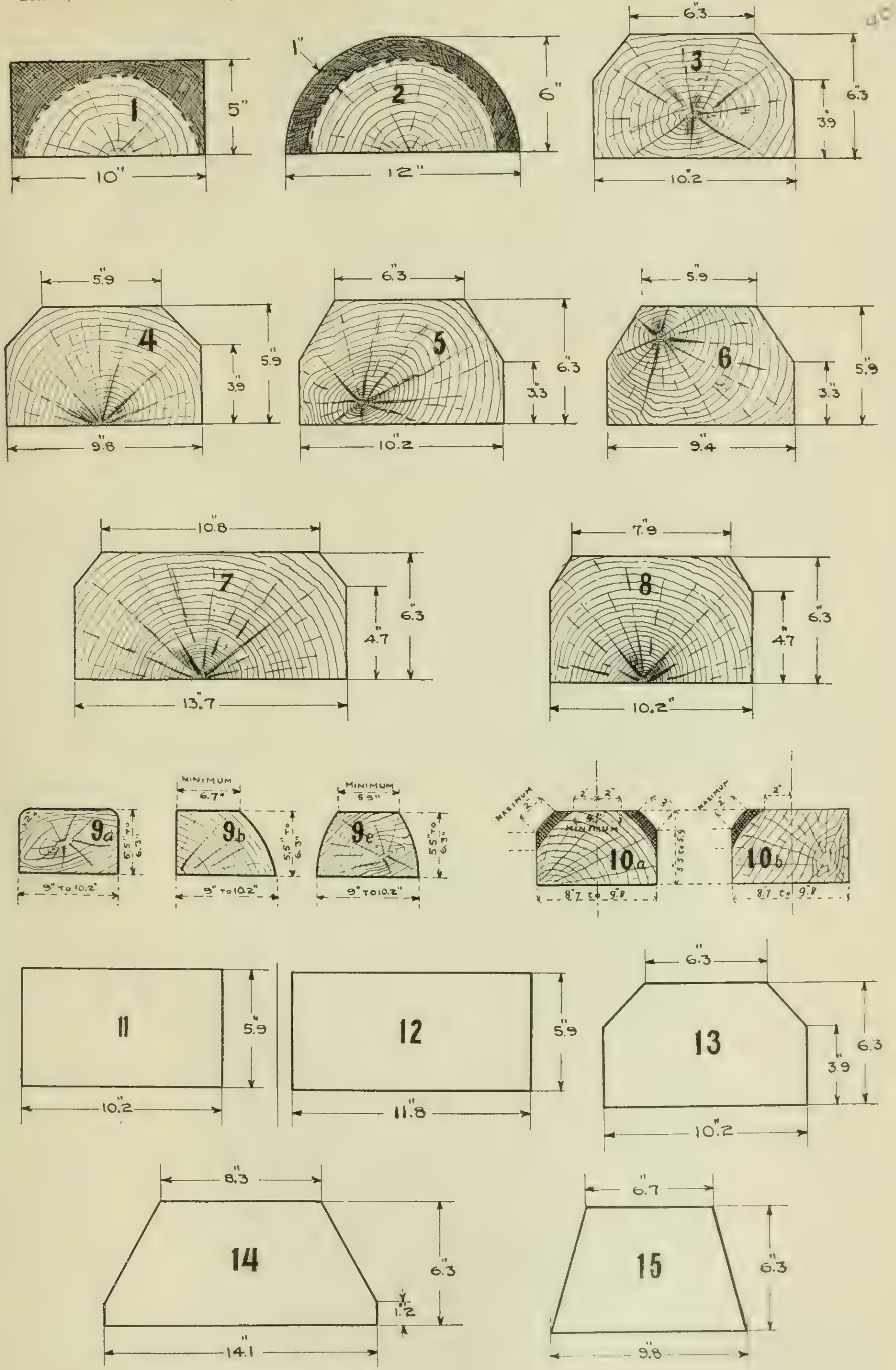
Attention is called to the superior mode of fastening the rail to the tie generally in use all over the better European lines. Spikes are found rarely, as it has been found that the tearing incident to driving spikes into wood and the subsequent "working" of spikes, rapidly renders ties unfit for use. Screw spikes and wooden treenails are commonly employed. Holes are bored in the ties at proper points, sometimes by machinery, in other cases by hand. The screw spikes or the treenails are then inserted and screwed or driven in. The screw spikes do not injure the fiber and hold the rail very firmly to the tie. Such a thing as working out is absolutely unknown. The managements without exception expressed themselves to the effect that the use of screw spikes had materially aided in prolonging the life of the timber. A recent invention is now being tried on several lines, which would permit the use of such ties where for any reason the wood around the screw spike has begun to rot so as to cause loosening of the screw spike. A hollow wooden cylinder, several times the diameter of a screw spike, called a "düvel" is screwed into the enlarged hole left by the loosened screw spike, and the latter is then screwed into the central hole of the düvel. The manufacturers claim that an additional life of four or more years is assured the tie by this method.

The chairs in use on some lines are fastened by means of treenails. These are made of various hard woods and have given universal satisfaction.

METHODS OF IMPREGNATION.

INTRODUCTION.

The methods of impregnation now in use in Europe are, with two exceptions, the same that have been in use for fifty years. The prices of timber, of labor, and of impregnating materials have changed somewhat, and there have been changes in detail, but on the whole the processes are the same. Wood impregnation is carried on by nearly all railroad, telegraph, and mine companies, because it is an absolute financial necessity. The price of timber is so high that its lasting powers under ordinary conditions are too short to assure its economic use. The processes now used differ in the character of the material used and in the cost of operation. The one used in England, Belgium, and France—the creosoting process—is the most costly and at the same time the most effective in preserving the wood. In Germany and Austria a process making use of zinc chloride and tar oil is now in use, which is cheaper than the English system, and in some other countries the still cheaper zinc chloride process is used. The reason why certain processes are used in the different countries is difficult to define. In England and France, where the cost of timber is very high, it pays to use the very best process; in Germany and Austria certain processes are now used because the various interests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4.7"
13.7"
8
7.9"
6.3"
4.7"
10.2"
9a
2"
5.5" to 6.3"
9" to 10.2"
9b
MINIMUM
6.7"
5.5" to 6.3"
9" to 10.2"
9c
MINIMUM
5.9"
5.5" to 6.3"
9" to 10.2"
10a
MAXIMUM
2"
2"
2"
3"
4"
MINIMUM
5.5 to 5.9
8.7 to 9.8
10b
MAXIMUM
2"
2"
8.7 to 9.8
11
5.9"
10.2"
12
5.9"
11.8"
13
6.3"
6.3
3.9
10.2"
14
8.3"
6.3"
1.2"
14.1"
15
6.7"
6.3"
9.8"

Forms of Ties used on some European Railways.

[For explanation see list of illustrations.]

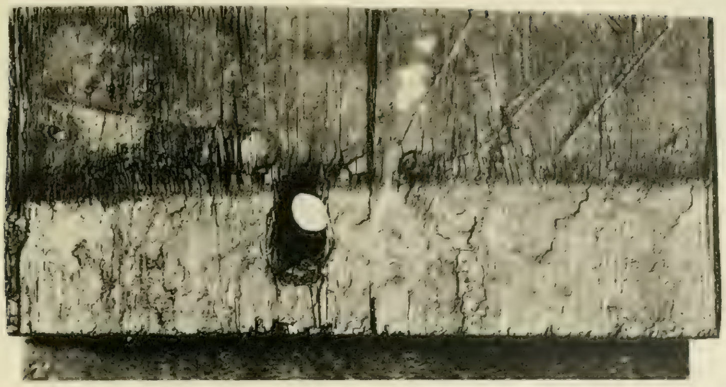


Fig. 1. Baltic pine tie, showing small wear of wood under chair, and of spike hole; 16 years service.

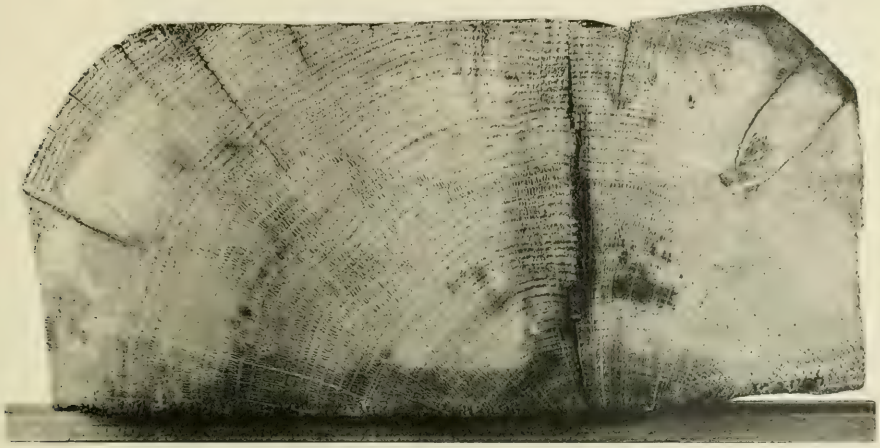


Fig. 2. Belgian oak tie; 18 years service.

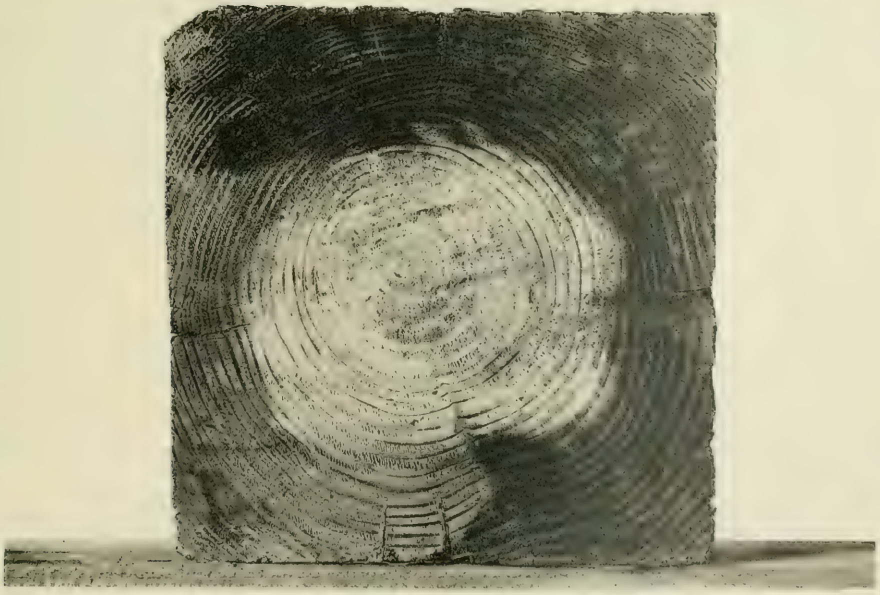


Fig. 3. Fence post of Baltic pine, 40 years old, impregnated with tar oil.

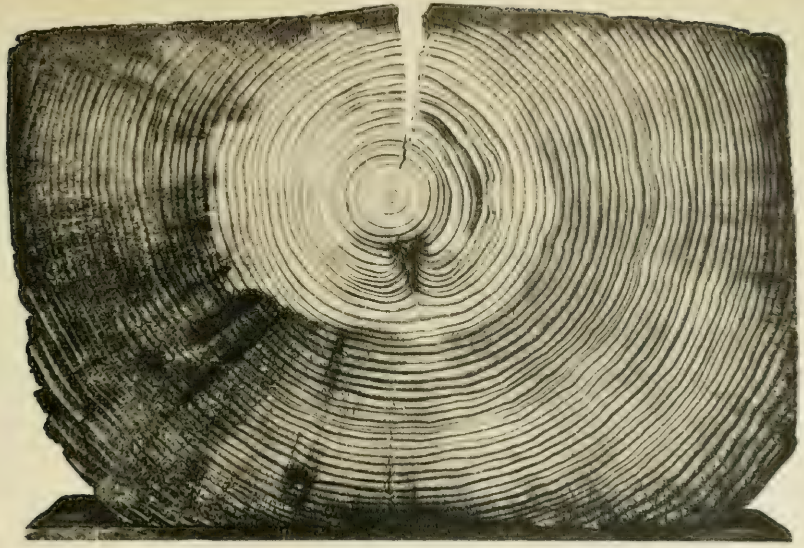


Fig. 1. New Baltic pine tie from Prussian railway, treated with chloride of zinc and tar oil.

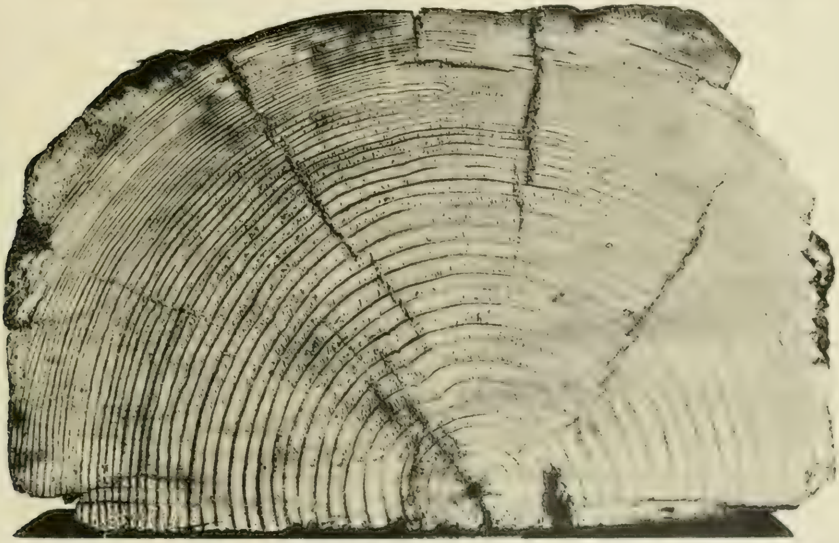


Fig. 2. Baltic pine tie laid in Prussia (Marschbahn) in 1885, treated with chloride of zinc and tar oil.

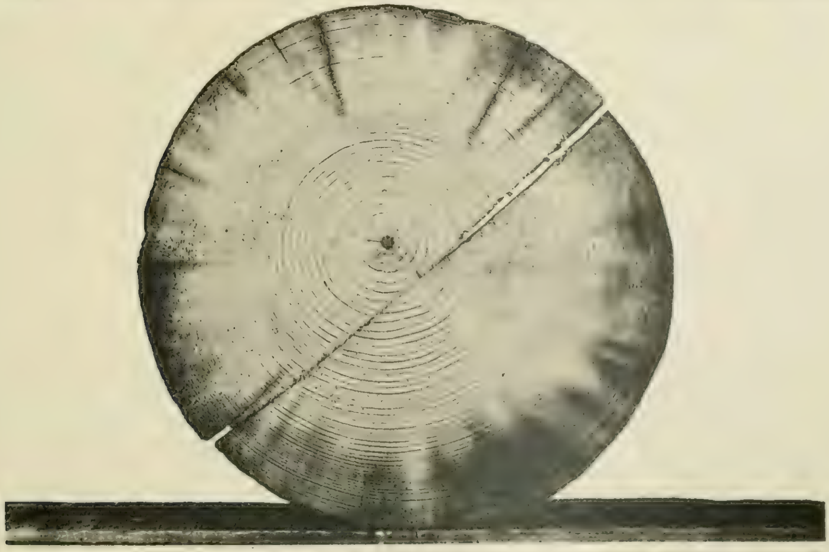
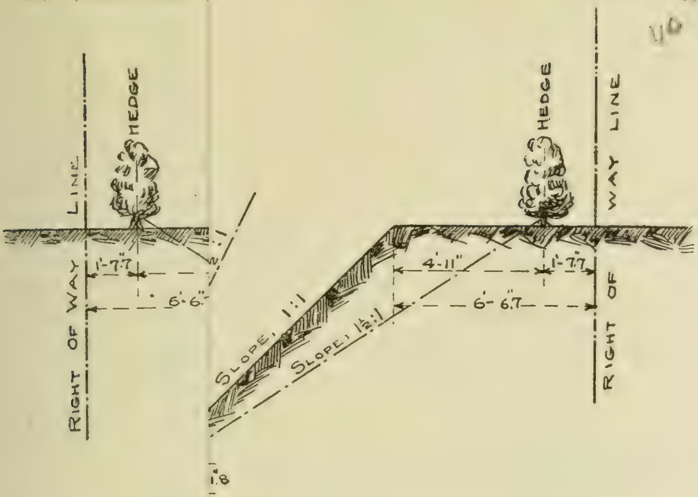
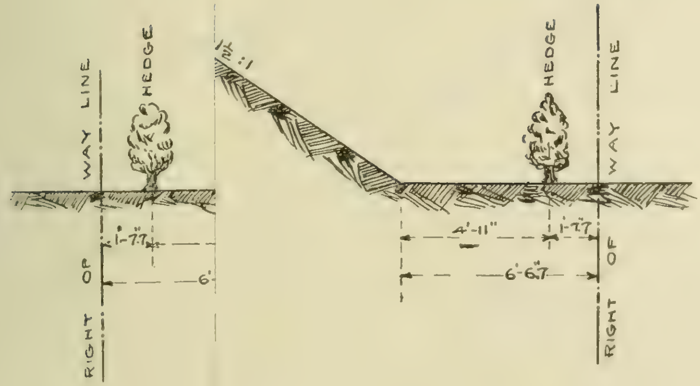


Fig. 3. Section of telegraph pole, Imperial German Postal service, treated with tar oil; in service since 1873.



HEDGE
RIGHT OF WAY LINE
1'-7.7"
6'-6"
2:1
SLOPE, 1:1
SLOPE, 1½:1
HEDGE
WAY LINE
4'-11"
1'-7.7"
6'-6.7"
RIGHT OF
1.8

NOTE: IN ALL CASES THE BOTTOM OF THE DITCH IS 11.8"



HEDGE
RIGHT OF WAY LINE
1'-7.7"
6'
1½:1
HEDGE
WAY LINE
4'-11"
1'-7.7"
6'-6.7"
RIGHT OF

PLATE XV. u

40

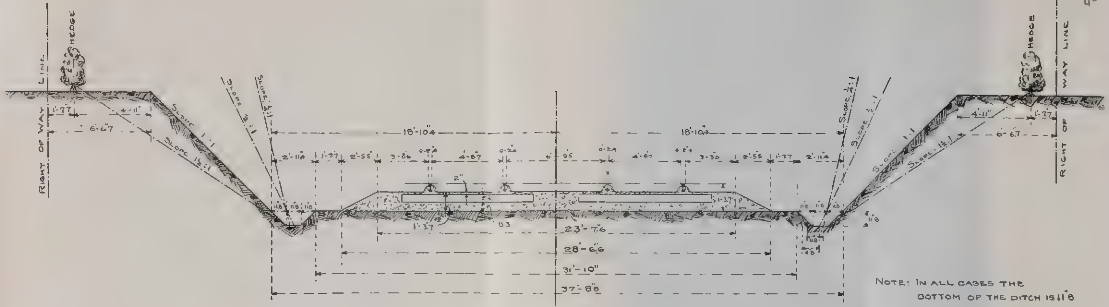

RIGHT OF WAY LINE
HEDGE
SLOPE 1:1
SLOPE 1½:1
SLOPE ¾:1
SLOPE ½:1
1'-7.7
4'-11"
6'-6.7
18'-10.4"
2'-11.4
2'-5.5
3'-3.6
0'-2.4
4'-8.7
6'
9.5
2"
1'-3.7
8.3
23'-7.6
28'-6.6
31'-10"
37'-8.8
11.8
NOTE: IN ALL CASES THE BOTTOM OF THE DITCH IS 11.8"

FIG. 1.—SECTION IN A CUT.

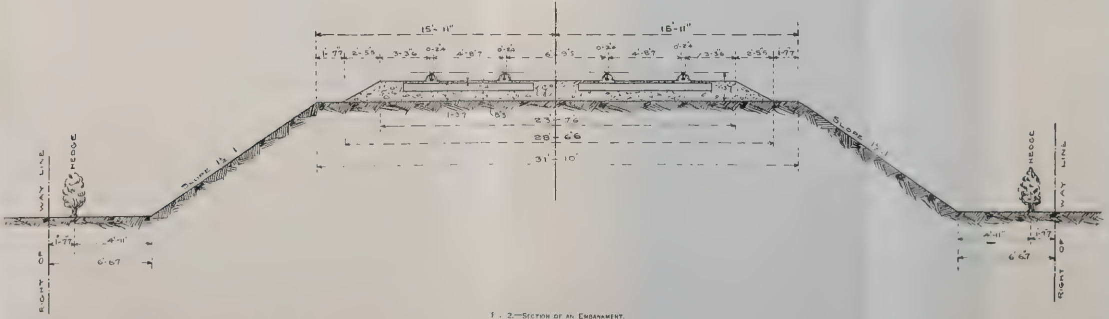

15'-11"
1'-7.7
2'-5.5
3'-3.6
0'-2.4
4'-8.7
6'
9.5
1'-3.7
8.3
23'-7.6
28'-6.6
31'-10"
SLOPE 1½:1
HEDGE
RIGHT OF WAY LINE
4'-11"
6'-6.7

FIG. 2.—SECTION OF AN EMBANKMENT.

CROSS SECTION OF ROADBED WESTERN RAILWAY OF FRANCE concerned claim that their past experience with one or more processes has led them to prefer one or the other. Records have been kept on most railroads with great fidelity, i. e., records which deal with the number of renewed and replaced treated ties. Some of these records deal with ties treated with different processes at almost the same periods of time in one and the same country. These are of particular value as indicating the comparative value of the treatments used. Unfortunately the trial of processes in localities where the factors of soil, climate, rainfall are approximately the same are very few in number. In Germany the writer learned of two trial stretches of track where experiments are being carried on now in a way similar to that described for the one started in Texas this summer. One of these is on the Prussian railways near Berlin, the other between Munich and Augsburg in Bavaria. The results obtained on the Prussian line were not accessible. The track near Munich was laid with a small number of ties in 1888. It is as yet too soon to expect final results, but the results obtained up to date are of sufficient value to warrant giving them. For convenience they are given in two tables, showing the detailed removal of the ties.

Table II gives the results with ties which were seasoned for some months after treatment, while the results shown in Table III were obtained with ties laid soon after treatment. Table IV gives the percentage removal, calculated from Tables II and III.

TABLE II.

[All ties laid in 1889. Ties seasoned before laying. Number of ties laid in all cases, 121.]

Kind of timber.	Treatment.	Ties removed, by years.							Total.
		1894.	1895.	1896.	1897.	1898.	1899.	1900.	
Oak	Untreated	......	......	......	......	3	3	......	6
Pine	do	14	14	10	2	13	15	31	99
	Treated with zinc chloride	......	......	......	......	1	4	6	11
Spruce	Untreated [a]	76	37	7	1	......	......	......	121
		......	......	......	......	23	30	23	76
	Treated with zinc chloride	......	......	3	4	6	26	23	62
	Mercuric chloride	......	12	42	21	19	9	2	105
Beech	Untreated [a]	103	6	2	10	......	......	......	121
		......	......	......	19	47	45	12	121
		......	......	......	......	......	......	7	7
	Treated with zinc chloride	......	......	2	2	4	7	7	22
	Red heart timber	......	......	3	......	11	6	16	36

[a] Double sets of figures show double renewal.

TABLE III.

[All ties laid in May, 1888. Ties not seasoned before laying. Number of ties laid in all cases, 121.]

Kind of timber.	Treatment.	Ties removed, by years.								Total.
		1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	
Oak	Untreated	......	......	......	4	......	5	2	......	11
	Treated with zinc chloride	......	......	......	......	......	......	......	3	3
Pine	Untreated	......	59	6	9	4	11	11	21	121
	Treated with zinc chloride[a]	......	......	......	......	......	......	......	12	12
		......	......	......	......	1	10	3	10	24
	Mercuric chloride	......	......	......	1	......	3	3	3	11
	Copper sulphate	......	......	......	......	......	4	......	16	20
Spruce	Untreated[a]	84	36	......	......	1	......	......	......	121
		......	......	......	......	39	58	13	19	121
		......	......	......	......	......	......	......	4	4
	Treated with zinc chloride	......	......	......	3	13	30	15	17	78
	Mercuric chloride	......	......	15	45	24	14	2	10	110
Beech	Untreated[a]	112	8	......	1	......	......	......	......	121
		......	......	......	98	14	5	3	1	121
	Treated with zinc chloride, no red heart.[a]	......	......	......	......	......	......	72	34	96
		......	......	1	......	11	11	14	18	53
	Zinc chloride, red heart	......	......	......	1	......	14	17	16	48

[a] Double sets of figures show double renewals.

TABLE IV.—*Summary showing per cent of ties removed.*

Kind of timber.	Untreated.		Zinc chloride.		Mercuric chloride.		Copper sulphate.	
	Not seasoned.	Seasoned.	Not seasoned.	Seasoned.	Not seasoned.	Seasoned.	Not seasoned.	Seasoned.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Oak	9.0	4.9	2.4	......	......	......	......	......
Pine	109.9	81.8	19.8	9.0	16.5	......	9.0	......
Spruce	203.3	162.8	64.4	51.2	......	......	90.9	6.7
Beech	279.32	205.7	43.8	18.1	......	......	......	......
Beech, red heart	......	......	39.6	29.7	......	......	......	......

These tables require little comment, as the figures tell their own story. By consulting Table IV it is possible to deduce the following:

EFFECT OF SEASONING AFTER TREATMENT.

That seasoning after treatment increases the life of the treated as well as the untreated timber is very evident even with this small number of ties. Note that in twelve years twice as many untreated oak ties came out as did of the dried ones. The same difference is noticeable with the treated timbers, particularly with pine, spruce, and beech, because more of these came out as a whole than of the oak. Note beech treated with zinc chloride, dried, 18.1 per cent, not dried, 43.8 per cent; pine treated with zinc chloride, dried, 9 per cent, not dried, 19.8 per cent.

RESULTS OF TREATMENT.

The experiment has gone far enough to show that treatment increases the length of life of the timber. Taking the timber which decayed most rapidly—the beech—it appears that treatment with zinc chloride increased the length of life more than three times. Thus, all of the 121 untreated ties had come out at the end of the seventh year (the greater number at the end of the fifth). These were all replaced, and again they all came out in seven years. This is an extremely valuable showing, as it demonstrates conclusively that the test made in this region is a fair one, for when the results are so exactly alike in two successive periods of seven years it is probable that the remainder will prove equally trustworthy. Turning now to the treated ties, we find that after eleven years 82 per cent of those treated with zinc chloride are still in service. With the spruce the results are not as favorable, for here only 49 per cent were in service after eleven years. With oak the effectiveness of treatment had not shown itself sufficiently to allow of any conclusion.

As for the different treatments employed, the results are somewhat at variance for the different timbers. With the pine the copper sulphate gave better results than the zinc chloride (copper sulphate, 16.5 per cent removal; zinc chloride, 19.8 per cent removal. For ties, not dried, and copper sulphate, no removals; zinc chloride, 9 per cent removals for seasoned ties). No tests were made with copper sulphate with the other timbers. Mercuric chloride (corrosive sublimate) gave better results than zinc chloride with pine, and poorer results than zinc chloride with spruce. The differences are very small, however.

The most important lesson to be learned from this experiment is the fact that here the principle of comparative tests under similar circumstances was carried out under rigid scientific inspection. Similar timbers were treated by the same person and with the view of answering a definite series of questions. The only objection that can be made is that the number of ties used was too small.

If all the ties treated in the United States were incorporated in an experiment of this kind, conducted not only in one place but in all sections of the country, results would be forthcoming whose value can fairly be appreciated by this test of the Bavarian Government. The writer was impressed with the business-like method with which those in charge of railway affairs in that country were attempting to answer the question of timber treatment.

Some interesting comparative results were obtained by several Austrian railways. These roads, several of them being private corporations, had to deal with the impregnating question with the idea of finding as cheap a process as possible. They impregnated various stretches with different materials and kept records for a number of years.

A graphic representation of the length of life of ties treated by various processes on the Imperial Railway of Austria is shown in figure 19 (published in 1898). The vertical lines represent years of service, the horizontal lines the renewal in per cents, each line representing 5 per cent. The diagram is very instructive, as it demonstrates several points. In the first place, it shows that the average life of unimpregnated pine ties, on the particular line shown, is about six years, while the same ties when impregnated with zinc chloride lasted on an average twenty years, and probably more, as there were still 18 per cent in service after twenty-five years. It is true that these ties were in station yards, but that detracts little from the general results, so far as the matter of decay is concerned.

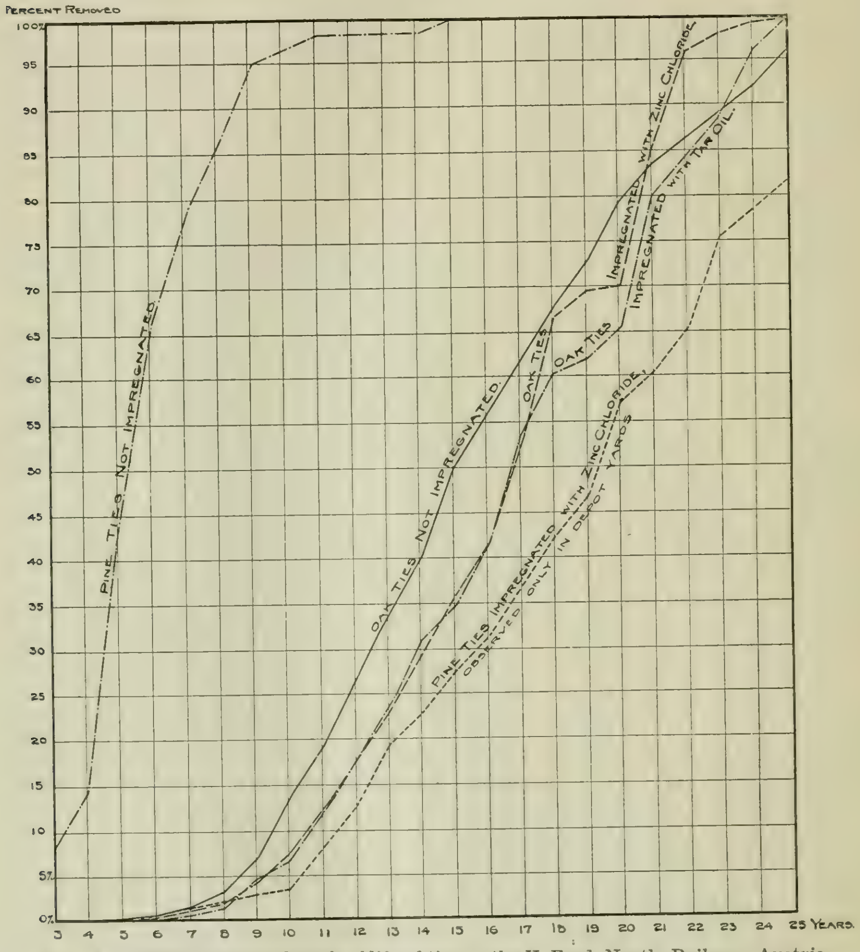
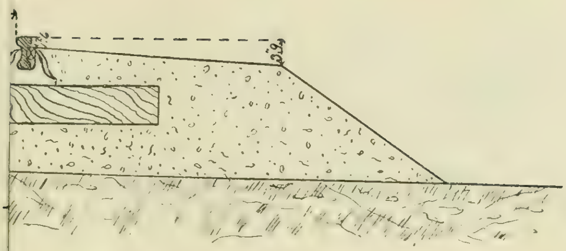


FIG. 19.—Diagram showing length of life of ties on the K. Ferd. North. Railway, Austria.

Turning to the oak ties, we note a rather surprising state of affairs. It will be seen that the unimpregnated oak ties lasted on an average as long as those impregnated with zinc chloride or tar oil, while those impregnated with tar oil came out before those treated with zinc

PLATE XVI.

44


3.9

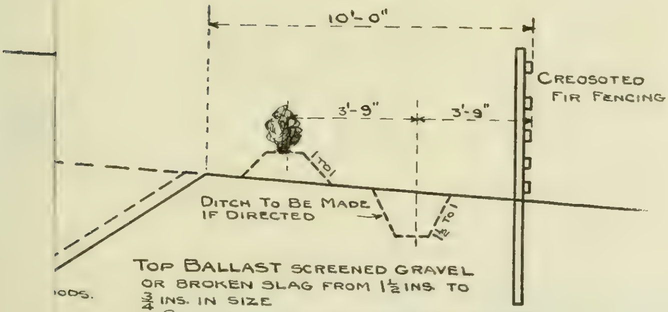

10'-0"
Creosoted Fir Fencing
3'-9"
3'-9"
1 to 1
1 to 1½
Ditch To Be Made If Directed
Top Ballast screened gravel or broken slag from 1½ ins. to ¾ ins. in size
Sleepers to be covered 1 in. thick.
oods.
one or rough slag filling
d Earthenware Pipe Drain.

PLATE XVI.

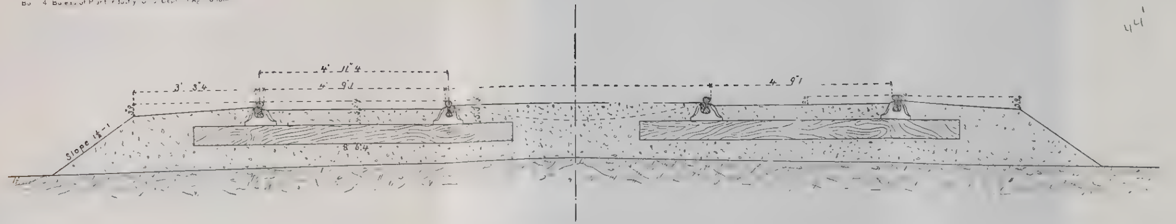

4'-11"4
3'-3"4
4'-9"1
4'-9"1
8'-6"4
Slope 1½-1

Fig. 1.—Section of Roadbed, Orleans Railway of France.

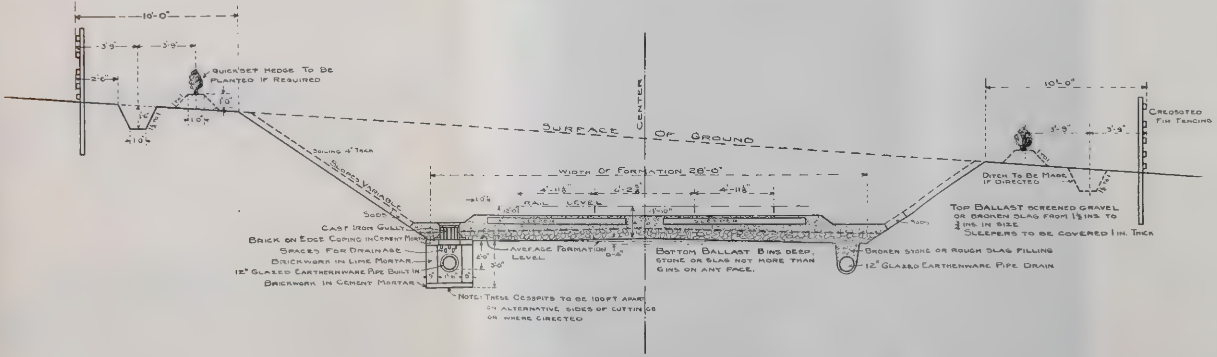

10'-0"
3'-9"
3'-9"
2'-6"
1'-0"
1'-0"
1'-0"
Quick'set Hedge To Be Planted If Required
Surface Of Ground
Center
Soiling 4" Thick
Slopes Variable
Width Of Formation 28'-0"
4'-11⅛"
6'-2⅝"
4'-11⅛"
1'-0¼"
Rail Level
2'-6"
1'-10"
Sleeper
Sleeper
Sods
Cast Iron Gully
Brick on Edge Coping in Cement Mortar
Spaces For Drainage
Brickwork in Lime Mortar.
12" Glazed Earthernware Pipe Built In
Brickwork in Cement Mortar
5"
1'-6"
8"
2'-0"
3'-0"
Average Formation Level
0-4"
Note: These Cesspits to be 100 ft apart on alternative sides of cuttings or where directed
Bottom Ballast 8 ins deep, stone or slag not more than 6 ins on any face.
Broken stone or rough slag filling
12" Glazed Earthenware Pipe Drain
Top Ballast screened gravel or broken slag from 1½ ins to ¾ ins in size
Sleepers to be covered 1 in. Thick
Sods
10'-0"
3'-9"
3'-9"
Ditch To Be Made If Directed
Creosoted Fir Fencing

Fig. 2.—System of Ballasting, Great Northern Railway. Section of Cutting on Straight.

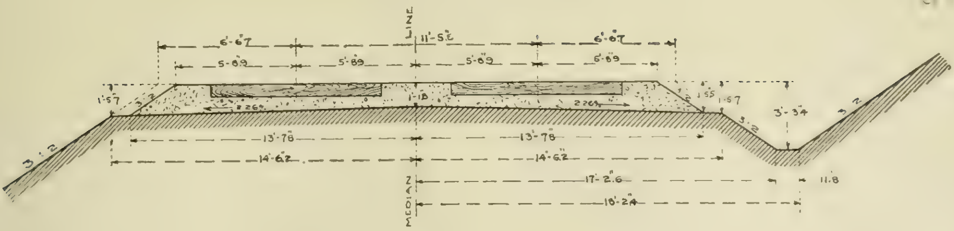

LINE
MEDIAN
6'-6.7"
11'-5.8"
6'-6.7"
5'-8.9
5'-8.9
5'-8.9
5'-8.9
1'-5.7
1'-1.8
2.26%
2.26%
1'-5.5
1'-5.7
3'-3.4"
3:2
3:2
3:2
3:2
13'-7.8"
13'-7.8"
14'-6.2"
14'-6.2"
17'-2.6"
11.8
18'-2.4"

Fig. 1.—Section for Double Track, with Sand Ballast.

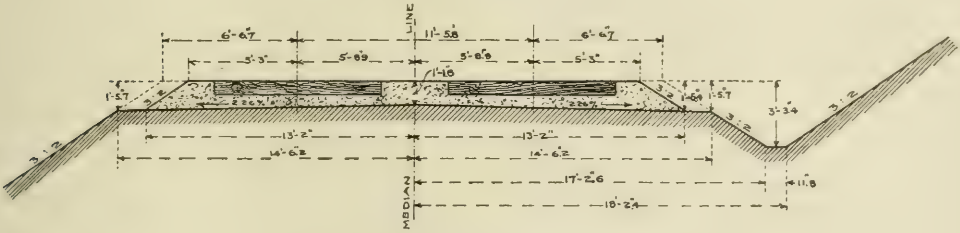

LINE
MEDIAN
6'-6.7"
11'-5.8"
6'-6.7"
5'-3"
5'-8.9
5'-8.9
5'-3"
1'-1.8
1'-5.7
2.26%
2.26%
1'-6.4
1'-5.7
3'-3.4
3:2
3:2
3:2
3:2
13'-2"
13'-2"
14'-6.2
14'-6.2
17'-2.6
11.8"
18'-2.4"

Fig. 2.—Section for Double Track, with Gravel or Rock Ballast.

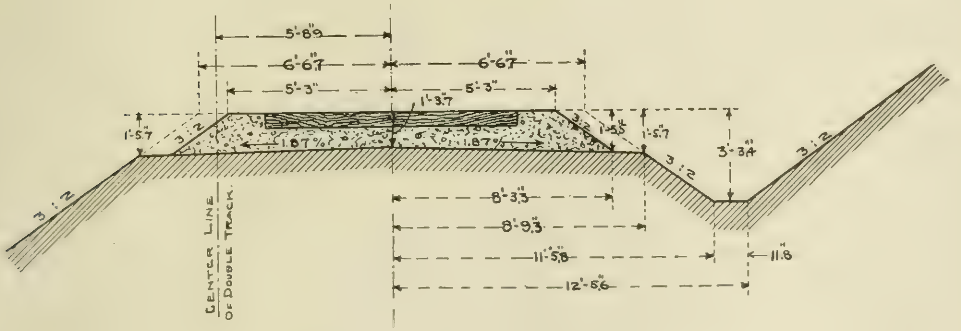

5'-8.9"
6'-6.7"
6'-6.7"
5'-3"
5'-3"
1'-3.7"
1'-5.7
1.87%
1.87%
1'-5.5"
1'-5.7"
3'-3.4"
3:2
3:2
3:2
3:2
Center Line
Of Double Track.
8'-3.3"
8'-9.3"
11'-5.8"
11.8"
12'-5.6"

Fig. 3.—Section for Single Track, with Sand Ballast.

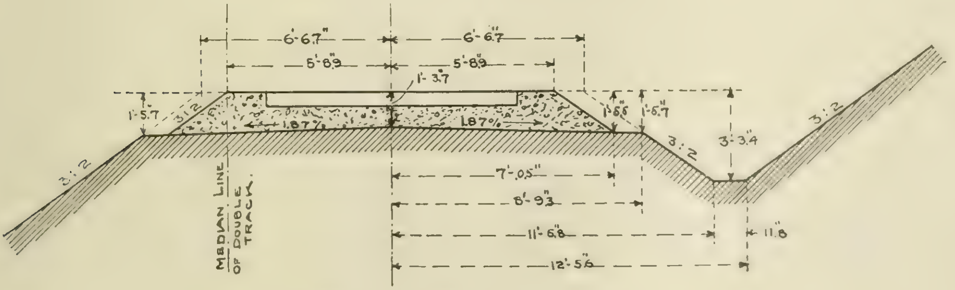
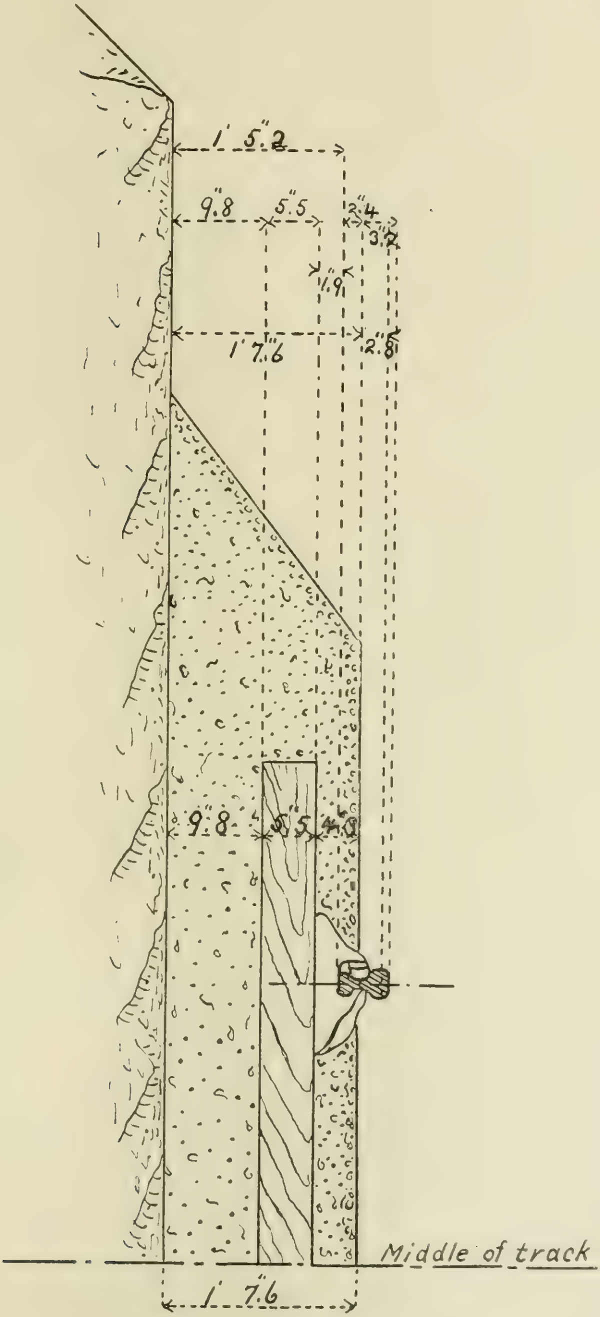

6'-6.7"
6'-6.7"
5'-8.9
5'-8.9
1'-3.7"
1'-5.7
1.87%
1.87%
1'-5.5"
1'-5.7"
3'-3.4"
3:2
3:2
3:2
3:2
Median Line
of Double Track.
7'-0.5"
8'-9.3"
11'-6.8"
11.8"
12'-5.6"

Fig. 4.—Section for Single Track, with Rock Ballast.

Sections for Track, Bavarian State Railways.


1' 5.2"
9.8"
5.5"
2.4"
3.7"
1.9"
1' 7.6"
2.8"
9.8"
5.5"
4.3"
Middle of track
1' 7.6"

FRANCE WESTERN RAILWAY. SECTION OF ROADBED.

chloride. In view of the fact that the experience of all other roads has shown the unquestioned superiority of the tar-oil impregnation, one can draw but one conclusion from this diagram, and that is that the work originally done with zinc chloride as well as the tar oil was probably very poorly done. It is very much to be regretted that the exact prices of treatment and the amount of material used could not be obtained.

One could hardly find a more striking instance of the fact that impregnation is worth nothing at all if it is not well done.

Turning now to another series of data, first published in 1885, we find additional facts which are given here, as they show distinctly the relative results on some Austrian roads. The vertical lines show the number of years which the particular timbers have been in use, while the horizontal lines indicate the percentage removal. Beginning with the oak chart, we see that unimpregnated oak ties lasted, on an average, eleven years, while those treated with zinc chloride were for the most part still in position after twelve years, and of those treated with tar oil still more. The long life of untreated timber is striking and requires some explanation, particularly as we are liable to give the name of oak to any oak. The European oak is a kind of timber which belongs to the white-oak class. It is very much superior to our white oak, however, and when properly seasoned (as is the case in most countries) it lasts about twelve to fourteen years. The Austrian Southern Railway get fifteen to sixteen years' life out of them, and they claim that these ties came out because of wear rather than decay. It is important to note that on the diagram shown there are two lines giving duration of unimpregnated ties, and that these lines show very different lasting powers. In one case 115,790 ties are accounted for; in the other, 7,660. The two series probably came from different sections of country, and seem to emphasize the

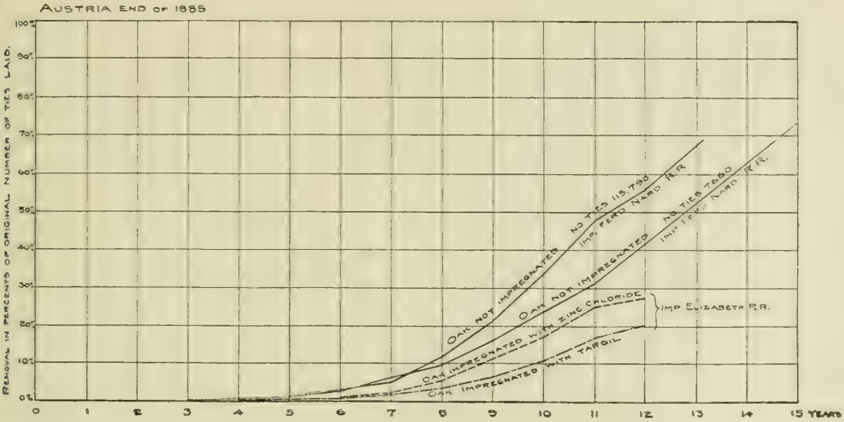


FIG. 20.—Diagram showing removal of impregnated and nonimpregnated oak ties.

fact that only with large numbers of ties and under various conditions, kept under strict observation, can reliable data be obtained.

The zinc chloride ties and the tar-oil ties show duration until the twelfth year. After that no record was obtainable. To judge from the trend of the lines it seems probable that they would have lasted for many years.

CONCLUSIONS.

From this series of ties one may conclude that in Austria oak ties last twelve to fourteen years, that when treated with zinc chloride they give a much longer service, and still more when treated with tar oil.

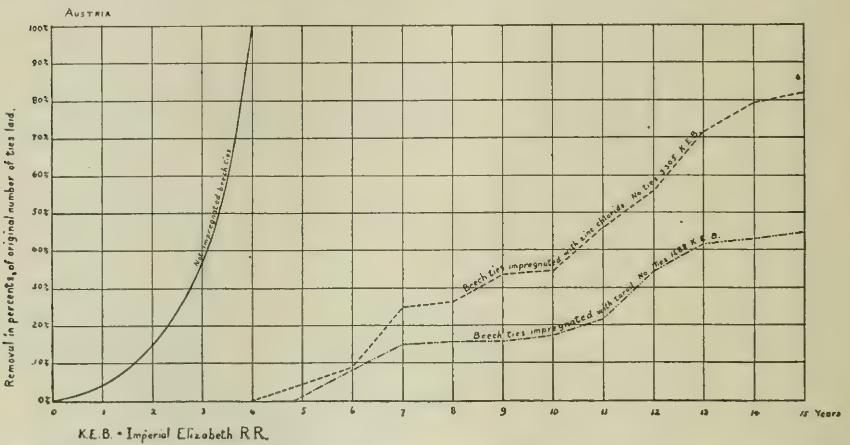


FIG. 21.—Diagram showing removal of impregnated and nonimpregnated beech ties (trial track).

Turning now to beech ties, figure 21 shows the result of an extensive test on the Imperial Elizabeth Railroad of Austria. It is a striking picture of the comparative results and needs little com-

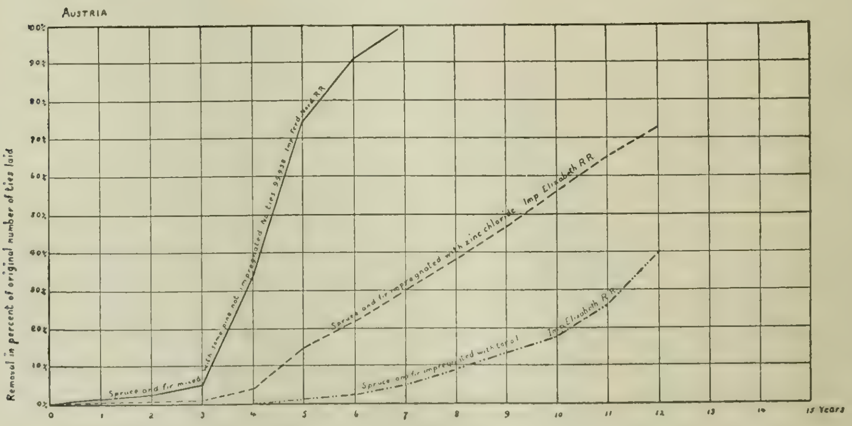


FIG. 22.—Diagram showing removal of impregnated and nonimpregnated spruce and fir ties.

ment. The unimpregnated timber was all gone after four years. The ties treated with zinc chloride lasted on an average eleven to twelve years, and those impregnated with tar oil over fifteen years. It shows that zinc chloride more than doubled the length of life of this timber, which rots more rapidly than almost any other. The large number of ties used is also a favorable point. The zinc chloride compares favorably with the tar oil. No record of how the treatment was made was obtainable.

Equally striking is the table showing the results with spruce and fir ties.

The average life of these ties may be given as: Unimpregnated, four to five years; impregnated with zinc chloride, nine to ten years; impregnated with tar oil, twelve years or more.

Here again the zinc chloride doubled the length of life.

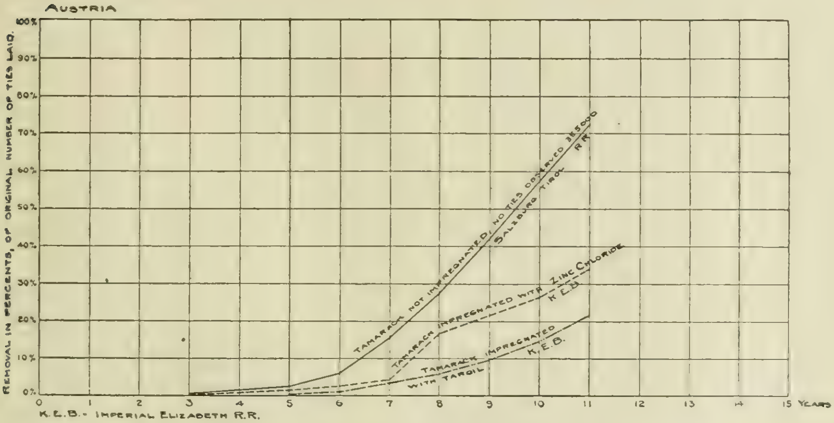


FIG. 23.—Diagram showing removal of impregnated and nonimpregnated tamarack ties.

Figure 23 gives the result with tamarack ties on the Imperial Elizabeth Railway and the Salzburg Tirol Railroad.

The result may be given as follows: Unimpregnated, nine to ten years; impregnated with zinc chloride, probably thirteen years; impregnated with tar oil, over fifteen years.

This diagram is not so satisfactory as the rest, because the curves do not extend out far enough. One can, therefore, only conjecture what would have been the results by following out the curves as given. Attention must be called to the fact that the European tamarack is a very resinous wood which lasts almost as long as oak. It is entirely different from our tamarack.

Pine ties are among those which decay most rapidly. In England the Baltic pine untreated lasts about eight years, while the same timber lasts only four years in Russia. On figure 24 it will be noted that the first curve, obtained from data involving 55,270 ties on the Imperial Northern Railway of Austria, shows an average life of untreated pine (Scotch pine[a]—*Pinus sylvestris*) of five to six years. The second curve shows a lasting of about eight years, data coming from six German lines involving 880,000 ties. The curves 3 and 4 show remarkable lengthening of life by zinc chloride treatment, also by tar-oil treatment. The curves are not continued out far enough, but they show a probable average of life of over seventeen years for the zinc chloride treatment and considerably more for the tar-oil.

A comparison of the various tables permits of some conclusions as to the relative value of the different kinds of treatment according to Austrian experience, and also of the relative effects of the treatment on different timbers. In the first place the general results show that treatment of timber with zinc chloride increases the length of life of treated timber very materially and treatment with tar oil does so still more. The difference in effectiveness varies very materially with the kind of timber used. Beginning with oak ties treated with zinc chloride it appears that the average length of life of untreated ties is eleven to twelve years, of treated ties twelve to thirteen years. That is not a very great lengthening of life. One must not forget, however, that this oak, as has been pointed out, is an unusually resistant timber, and when reading these figures the American reader must not compare it with our oaks. The lengthening of life of tamarack ties (fig. 23) is much like that of the oak. It is a resistant timber naturally. When we come to the less resistant timbers, such as beech, pine, and spruce, the result of zinc chloride impregnation is surely very striking, particularly with the beech. With all of these timbers the length of life was more than doubled.

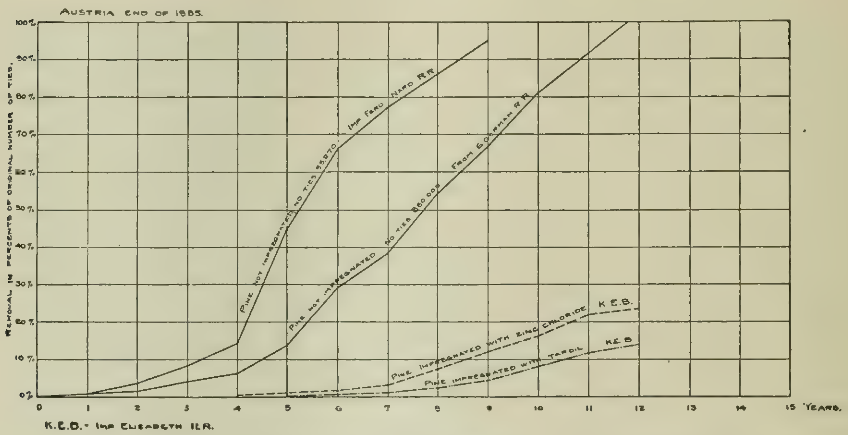


FIG. 24.—Diagram showing removal of impregnated and nonimpregnated pine ties.

The results obtained with the tar oil considerably exceed those shown with zinc chloride. A glance at the tables will suffice to show this without any further comment.

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[a] Scotch pine is called "Baltic" pine in most European contracts.

We come now to a brief consideration of the various methods themselves.

CREOSOTING.

There is probably no reason for discussing the value of the creosoting process in this report, for it is believed that there is no longer any question at this time as to its positive value, provided that it is well done, and under conditions which permit its economical use.

Creosoting is used on all English and on most French lines. It is also used in Belgium. So much has been written on the subject of creosoting timber that only a few points will be emphasized at this time, especially as the object of this investigation was to see results, rather than methods. A good deal of time was spent in the examination of creosoted Scotch pine in England. The Scotch pine is a kind of timber which corresponds closely to some of our Southern pines. It is a soft wood which would last but few years in an untreated condition. When treated according to the best English methods, ties made of this timber have lasted twenty-five years or more. A careful inspection was made of a stretch of track on the Great Western Railway where relaying was in progress. The custom of relaying entire stretches of track in vogue in England makes it possible to examine side by side many hundred ties of the same age. On Plate XIII, figure 1, is shown the section of a tie which had been in the track sixteen years. It is a good example of thousands of similar ties which were removed from a main line to be put into a secondary line. Especial attention is called to the small amount of wear of the hole which held the treenail and of the tie itself. This is due in no small part to the use of the chair, which distributes the load over a large surface. The use of a chair with a wider base has resulted in extending the life of ties on some roads for five to ten years.

The Bethell process of impregnation is used by most English lines. The injection results in a complete impregnation of the sapwood (Pl. X, fig. 1), with a very small penetration of the heartwood. This total impregnation of that part of the wood from which decay usually starts retards the destruction of this timber for many years. Whenever decay does start, it begins on the lower side (Pl. X, fig. 3) and progresses very slowly upward. It is rather remarkable that the heartwood remains sound for so long a time with so very small a penetration of the creosote on the lower side of the tie. It serves to emphasize the fact that the sapwood probably is the base from which the decay starts in most cases. A tie of the kind shown on Plate X, figure 3, will still be of service for many years.

The quality of creosote used is carefully controlled. Specifications have been printed by Chanute.[a] The cost of the creosoting process varies with the amount of creosote injected. The following prices from the balance sheet of one road for May, 1901, may be taken as a fair average at the present time:

	English money.		United States equivalent.
	s.	*d.*	
Clear sleeper	3	10.00	$0.950
Treatment:			
Creosote	0	6.74	.134
Coal and stores	0	4.18	.083
Wages	0	3.98	.079
	1	2.90	.296
Total cost of impregnated sleeper	5	0.90	1.246

In Belgium oak ties are treated much as in England. Ties were examined which had been in the track for fifteen years. They were sound and showed no changes. The sapwood, which is very narrow, is the only part which can be injected, yet the quantity of creosote which it absorbs is ample to protect the timber for long periods of time. The following is the average cost of the operation:

	French money.	United States equivalent.
	Francs.	
Tie (including adzing and boring)	6.000	$1.20
Creosote and labor (8 liters=18 pounds of creosote per tie)	.487	.10
Total	6.487	1.30

Note that the French Eastern Railroad put in 60 pounds.

The Belgian State Railway uses two kinds of creosote, boiling at 200° C. and 250° C., respectively.

In France the Eastern Railway has obtained the best results of any roads in Europe. This is due (1) to the unlimited amount of creosote of a high grade which they inject; (2) to their use of beech timber for ties. This is capable of absorbing the creosote so as to become almost completely penetrated. M. Dufaux, in an elaborate treatise on the process as practiced by the Eastern Railway, describes at length the methods in use by that company, and anyone contemplating the use of creosote is referred to this report. Through the kindness of M. Dufaux and M. Müntz the writer was enabled to examine a long stretch of track in which ties treated in the years

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[a] Chanute, Octave. The Preservation of Railway Ties in Europe (Am. Soc. C. E., vol. 45, p. 498, 1901).

1869–1873 were in position. Sections of these ties are shown on Plate XI. Their state of preservation was certainly remarkable. As a result of their experience with beech timber French engineers claim that it pays to inject as much creosote as the tie will hold. The extra pound or two will be amply compensated for by the greatly extended life of the timber. Oak ties lasted about fifteen years, and had to be removed because they were worn out; beech ties, as indicated, lasted thirty years.

The cost of the operation is given as 1 franc (20 cents) for oak ties and 2.25 francs (45 cents) for beech ties, exclusive of transportation or boring.

SUMMARY.

The use of creosote for preserving timber has been shown by the experience of the English and French lines to be beyond question a method which protects those parts injected with it absolutely. Such timbers as can be wholly impregnated with creosote will never rot; they may wear out because of mechanical abrasion.

ZINC CHLORIDE.

The zinc chloride treatment, once so generally in use, is gradually being abandoned, because tar oil is so much more effective. On a large scale it is now used only on some of the Austrian roads and on a few small German lines. The general results obtained on several Austrian roads and in Bavaria were discussed above. The Austrian Northern Ferdinand Railway still employs this process, because it has been doing so for many years, and as the road is soon to be turned over to the Government it regards the results which are being achieved to be sufficient for their present purpose. On the Austrian Southern Railway beech, oak, pine, and larch ties are in use, of which the first three have been impregnated with zinc chloride for four years.

This is too short a time to give results. The objections made to the zinc chloride are that it leaches out rapidly, and that it causes the spikes to wear out more rapidly. Attention is here called to the so-called decay of many ties impregnated with zinc chloride, especially near the spikes. The wood turns bluish in color, and gradually becomes brittle and pulverizes easily, so that the spikes no longer hold. This change is not due to decay, but to the acid formed in the wood. This attacks not only the wood fiber, but also the spikes. These changes in the chloride of zinc were first studied by Grittner, in Austria, and are referred to by Schneidt. They require further exhaustive study in this country, where this action of the zinc chloride is as yet little understood. Oak ties are in use on some parts of the southern Austrian system, but they are not impregnated, for the reason that they generally wear out before rotting.

Zinc chloride was formerly very widely used in Russia. On the Warsaw-Vienna line oak ties are used exclusively at the present time.

These are not impregnated. They cost from 2 to 2.15 rubles ($1.08 to $1.16) and the treatment with zinc chloride costs 30 kopecks (16 cents), which is considered very high, especially as it was found that under the conditions obtaining in Poland the length of life of an oak tie was increased but two years by the treatment. This the management regarded as too small an increase to justify the expense. On the Russian lines zinc chloride is used in treating Scotch pine, and apparently with good success. In Germany the chloride of zinc treatment by itself was given up for the most part after the year 1897.

It appears from the foregoing that but little impregnation is now being done with chloride of zinc. It is beyond doubt a splendid antiseptic, but the rapidity with which it leaches out has brought it into discredit with European engineers. The impression was gained that many railroad managements had overrated the value of chloride of zinc as an antiseptic. It was known in a general way that the salt leached out, and as a result stronger and stronger solutions of the salt were pressed into the wood. Nothing very definite is known even at this day as to the rate at which this salt leaches out. Schneidt has given some results in his paper,[a] but these are based entirely on some tests of ties which had been in the roadbed for three years, and in these he found the larger part of the zinc chloride gone. The records of past years in Europe take little cognizance of this leaching out or the influence on the lasting effect of increased or lessened amounts. Furthermore, the same treatment was applied to all timbers. It is well known that pine ties take up more solution than oak, and also that woods like oak, with a solid heartwood, take up very little solution except in the sapwood. The leaching out goes on differently in pine and oak, faster from the oak in some cases, and then again more slowly, depending upon the timber and on the thoroughness with which the impregnation was done.

The general impression gained was that for soft timbers, like the pines, spruces, and beech, the chloride of zinc treatment might give satisfaction where the increased length of life desired was short, owing to repeated renewals because of wearing out; but that it had proved unsatisfactory where a largely increased length of life was looked for. For hard woods, such as the European oaks, it did not pay, because the increased length of life obtained was entirely out of proportion to the cost of impregnation. The feeling in Germany is very well voiced by Schneidt, as follows (p. 16): "Oak ties, which last thirteen to fourteen years, ought to be impregnated with tar oil only, since the small increase in price of this treatment, as compared with the zinc chloride, can not be considered in view of the high prices of oak ties, and in view of the fact that tar oil, of all preservatives, is the only one which can give oak wood a decided increase in life." And again: "But even for pine ties * * * the treatment with zinc chloride is not satisfactory in the long run."

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[a] See Bibliography, p. 68.

The above is without question true for European conditions; but one can not apply the same reasoning to this country. In the first place, of our oaks, the white and post oak are not as high grade timber as the European oak, and our red, black, and swamp oaks are very much inferior. While the European oak takes little zinc chloride solution, our oaks take a good deal, especially the inferior ones. After all, it is largely a matter of prices. Where timber is not as expensive as it is in Europe, but where it is already costly enough to warrant treatment, a process which may not be the best, but which does increase the length of life and which is cheap, is certainly worth considering and worth trial. It costs about 80 cents to creosote a tie according to the best practice, and it pays to do this with the ties which cost $1.50, because thirty years of life are possible; but it hardly pays with ties costing but 40 to 50 cents. A consideration of the diagrams given on pages 44, 45, 46, 47, and 48 will be sufficient to convince anyone that zinc chloride does prolong the life of the treated timbers. Furthermore, a study of Mr. Curtis's paper will show that similar results have been obtained in this country.

ZINC CHLORIDE AND COAL-TAR OIL.

In Germany and Austria the larger number of ties are to-day being impregnated with a mixture of zinc chloride and tar oil. The tar oil penetrates but a short distance into the wood (see Pl. XIV), while the zinc chloride goes in to a considerable depth. The great advantage which this method is supposed to have over other processes is that the creosote prevents the leaching out of the zinc chloride. The cost is but little above straight burnettizing, as a small quantity of the coal-tar oil is deemed sufficient to prevent the leaching out of the zinc salt. Impregnation by this method has been carried on by a number of the German Government railways for some years, and it is claimed that the ties so treated last fifteen to sixteen years. Plate XIV, figure 2, shows a section of a Scotch pine tie laid on the Marschbahn in 1885. It will be noted that the wood is still sound, although there is little evidence of tar oil in the outer cells. Figure 19 shows some of the results as given by an Austrian line.

The writer examined a number of sections where ties treated with the double process were laid. In some instances the ties were well preserved after six years, although here and there rotted ones were found only a few years after laying.

The absorption of tar oil by the different ties varies between very wide limits. Some ties absorb very much higher quantities than others. This makes any control of this process very difficult, especially as one of the objects is not to put too much tar oil into a tie, so as to keep the cost down. A commission sent by one of the French railways to examine into the methods of impregnation with the mixture as now practiced in Germany reported adversely, claiming that the results obtained were not counterbalanced by the saving in the price of treatment. This commission recommended the use of tar oil alone.

The reasons given by this commission for the use of tar oil alone were that ties cost so much in France that, knowing the good results which follow the use of tar oil alone, it would pay to use the very best process known.

It is interesting to note in this connection that M. Merklen, in discussing the report made on the system of double impregnation by Besson, calls attention to the fact that on one of the German lines 17,375 ties were impregnated with the mixture of zinc chloride and tar oil. These ties were treated by two different companies. One lot was laid in 1895, the other in 1888. Of the former, after six years, 50 per cent had been renewed in 1901, while of the latter, after thirteen years, only 15.86 per cent had been removed. This shows most strikingly that, with one and the same process, exceedingly poor and very good results can be obtained, depending upon the way in which the work is done.

It is without doubt true that some of the results obtained on the German lines with this process are very satisfactory, although, as Mr. Chanute has pointed out, this is often due to the better drainage and ballasting. In view of the fact that some of the lines now using this method of treatment are actively engaged in searching for better processes, an unqualified indorsement can not be given to this one. Where a first-class tar oil can be obtained and can be pressed into the wood in sufficient amounts, the process may be worth trying. A poor tar oil, which will volatilize readily, is worse than nothing.

The ideal method of using the two solutions might be to inject the zinc chloride first, dry the timber somewhat, and then inject the tar oil. The difficulty here is to control the amount of tar oil injected. This process is of course out of the question at this time, because no double handling would pay. The new Alderdyce process injects first of all zinc chloride, and then tar oil, in one and the same operation.

The comparative price of treatment of zinc chloride alone and of the double process has been concisely tabulated in Mr. Chanute's report as follows:

TABLE V.

[Cents per tie.]

Timber.	With zinc chloride.		With zinc creosote.		With creosote and drying oven.		Boiling in creosote.	
	First class.	Second class.	First class.	Second class.	First class.	Second class.	First class.	Second class.
Pine	15.60	12.00	19.20	14.40	53.76	40.32	56.64	42.00
Oak	12.00	9.12	15.60	12.00	26.85	20.16	28.80	21.60
Beech	18.80	12.48	20.40	15.36	56.64	42.00	59.28	44.40

HASSELMANN TREATMENT.

One of the great drawbacks of most preserving processes in use at the present time is that the salts injected are soluble in water, and on that account leach out rapidly from the wood when the latter is brought into contact with moisture. During the last four years a process for treating timber has been presented to engineers, which makes the claim that the injected salts form an insoluble compound with the wood. The method of treatment differs from all those now in vogue, in that no pressure is used to inject the salts. The timber to be treated is put into closed cylinders, and a solution of copper sulphate, iron sulphate, aluminum sulphate, and a small amount of kainit is run in. By means of superheated steam the solution is brought to the boiling point. The timber is thus literally boiled in the solution for several hours. The process has numerous advantages to recommend it over the older methods. The salts used are cheaper than any of the other materials. The wood to be treated may be dry or wet. The treatment is cleanly and rapid. The iron and copper salts penetrate every fiber of the wood. This is a notable advance in the science of timber treatment. All salts heretofore injected remained in the cavity or lumen of the wood cells, left there when the water evaporated. In the present instance the salts penetrate the walls of the wood cells, and apparently form some insoluble compound with the wood substance. An investigation of this subject is now being made, with a view of determining what this insoluble compound is, and whether it will be destructive to the fungus cells. The chief value of the new process, however, lies in the fact that the injected salts are insoluble. The writer made a number of tests to demonstrate this fact, and is convinced of its truth. There are practical difficulties, however, which will have to be overcome. It has not yet been shown that wood thus impregnated is capable of resisting decay, and in view of the recent origin of the process it does not seem likely that results on a larger scale will be possible for some years. The first experiments made with this treatment were carried on in Bavaria by the Bavarian Government, and since that time a number of private companies have used this method of timber treatment.

The writer examined with care the ties treated by this process lying in several railway yards in Berlin, and on a stretch of track near Berlin; also several hundred of these ties on a stretch of track near Augsburg in Bavaria. Without going into details it may be said that, owing to attendant circumstances, it seems that the treatment as carried out on these stretches was done in a manner unfair to the system as advocated. In one case the extreme temperatures weakened the wood fibers, and in another case the treated ties were laid in the track very shortly after their treatment. The results obtained in the last years and any future results are therefore to be regarded with suspicion as far as these early tests are concerned.

The writer visited a large coal-mining village in the Bavarian Alps for the purpose of inspecting the results obtained with the Hasselmann treatment in the mines. The company operating these mines had after careful consideration built an impregnating plant, where they have been treating all of their mine timber for almost three years with the copper-iron-aluminum solution. Since 1895 they had been using chloride of zinc. The timbers treated are chiefly the Scotch pine (*Pinus sylvestris*), spruce (*Picea excelsa*), and fir (*Abies pectinata*). The sticks used, varying in age from 40 to 80 years, are about 8 inches in diameter, of which a large share is sapwood. Much of the wood seen in the yards ready for treatment had blue sapwood. This was not regarded as a defect by the manager of the treating works.

The timbers to be treated, after seasoning for some months, are placed in a cylinder, where they are heated in the solution up to a temperature of 130° C. for two hours. They are then taken out and stacked. After lying some six months they are built into the mine.

In August, 1898, the first timbers treated with the Hasselmann treatment were put in. Pine, spruce, and fir were treated. At the same time timbers treated with chloride of zinc were put in. All timbers in this mine are labeled with zinc labels giving the time of treatment, the month, and the year. Through the courtesy of the general manager, the writer was enabled to make a personal examination of the impregnated timbers in the mine and to have a good many treated timbers removed. The mine is what one might call a wet mine. The air is surcharged with moisture in the passages ("schlechte Wetter Stollen") giving probably as favorable an opportunity for leaching out of salts and the growth of fungi as could be desired. Both the vertical and horizontal timbers in the passages were covered with great masses of white fungus mycelium, and the general impression gained was that if timber would rot anywhere, it would be liable to do so there.

The conditions were very different in the passages with fresh, dry air. The manager stated that unimpregnated pine lasted three to four years in these localities. The same timbers lasted only a year and generally less in the very moist passages. Fir and spruce were very short lived in the wet passages. The experience of the managers led them to use unimpregnated timbers in temporary structures only.

Of impregnated timbers in the damper passages there are now in the mine: (1) Some pine treated with $ZnCl_2$ in 1896—i. e., they have given about three years' service. All fir and spruce came out before 1899. (2) The pine timbers treated with the copper-iron-aluminum mixtures. These were treated in August, 1898, and include pine, fir, and spruce. The larger per cent of these timbers is in good condition, but some of them, particularly the fir timbers, were beginning to decay. It is very much to be regretted that no unimpregnated timbers were placed with the impregnated ones at the time when the latter were placed in the mine. A good many timbers of pine and spruce of the 1898 impregnation were still standing in similar localities as the Hasselmann timbers, although, as has been said, most of them had been removed on account of decay. A great variability with respect to resistance to decay was noted. Too much stress can not be laid on this point, particularly as it is generally entirely disregarded. Some timbers absorb large quantities of zinc chloride, others very little; then again some timbers came from trees which had grown more rapidly than others, and therefore offered less resistance to decay than the denser timbers. One could not avoid being forcibly struck with this fact in this mine, where it was possible to deduce almost any conclusion as regards the rate of decay of the various timbers impregnated with zinc chloride. There were some pine timbers treated with zinc chloride which had been in the mine since 1895, while on the other hand many of those treated in 1898 were already rotted.

This test of the copper-iron-aluminum treatment in this mine is certainly a valuable one; in fact, the only one of this treatment which can be trusted up to date. It is rather early to state positively what its absolute value may be, but from the facts above stated one may conclude that it does retard the destruction of timber. In a mine where the life of a timber is reckoned by months it is already a very good sign to make a timber which would last twelve to eighteen months last thirty months. That it has done this in the Penzberg mine is beyond question. The owners of the mine are so well satisfied with this treatment that they have abandoned the zinc chloride treatment altogether. They regard the copper-iron-aluminum treatment as a good financial investment. The following figures were given by the general manager. They require no further explanation.

Cost of operation.

	German money.	United States equivalent.
Cost of timber:	*Marks.*	
Pine (*Pinus sylvestris*) per cubic meter	18	$4.50
Fir (*Abies pectinata*) do	18	4.50
Spruce (*Picea excelsa*) do	18	4.50
Salts, labor, etc do	4.01	1.00
License	1-2	.25-.50

To which is added interest.

Estimating that untreated pine lasts one year, they make the following estimate of cost for 1,000 cubic meters for two years:

	German money.	United States equivalent.
	Marks.	
1,000 cubic meters of unimpregnated wood for 2 years (lasting 1 year and then replaced), ignoring labor of replacing	36,000	$9,000.00
1,000 cubic meters of impregnated wood lasting only 2 years:		
Wood	18,000	4,500.00
License	1,000	250.00
Salts, etc	4,010	1,002.50
Interest	675	168.75
Total cost	23,685	5,921.25
Total amount saved	12,315	3,078.75

The further behavior of the timbers impregnated with the copper-iron-aluminum solution in 1898 at Penzberg will be watched with interest. The writer was impressed with the manner in which the impregnating work was done at Penzberg. The salts were carefully controlled; likewise the strength of the solution and the temperatures at which the wood was boiled. It was fully realized that one and the same kind of treatment will not apply to different woods.

NEW PROCESSES.

THE SENILIZATION PROCESS.

For about two years a French company has been impregnating wood, at first with creo-resinate of soda, now with magnesium sulphate, by means of an electric current. The timber to be treated is placed in a tank on a lead plate and is covered with a second plate. These plates serve as electrodes. The magnesium salt enters the wood cells by "electro-capillarity." Succeeding osmotic changes are supposed to bring about diffusion of the salt, so that all parts of the wood are finally impregnated. The electrolytic action of the current is said to cause the formation of a number of insoluble magnesium compounds in the walls of the wood fiber.

The cost of operation is said to be very small. Wood paving blocks treated with this process remained in good condition for two years on one of the bridges in Paris under heavy traffic.

EMULSION TREATMENT.

As one of the great objections to the use of coal-tar oil by itself is the great expense involved, any process which claims to make use of this substance in smaller quantities without reducing its efficiency is to be welcomed. The experiments have been made with various solvents of coal-tar oil, such as benzine, carbon bisulphide, etc., with the hope of introducing small quantities of the antiseptic, evenly distributed, and leaving it in the wood by distilling off the solvent. These have so far proved failures. The present method employs an emulsion of tar oil, made by dissolving various quantities of resin in the tar oil and adding a strong solution of soda lye (NaOH). In the resulting emulsion the tar oil is found in the form of exceedingly minute drops, which remain in the emulsified state for several weeks. This emulsion when pressed into wood distributes the tar oil evenly throughout the outer layers of the wood. In the account which the author gives of this new process he says that when tested as to its toxic action on some common molds the relative value of the tar oil and of zinc chloride was found to be 3:1. In other words, a relatively much smaller amount of tar oil will give the same protection to timber as a large amount of zinc chloride.

The process as outlined has the decided advantage over the zinc-chloride and tar-oil treatment in that a very much more perfect emulsion is formed, which allows of a much higher penetration of the antiseptic substance into the timber. No actual test of this method has yet been made.

CREO-RESINATE PROCESS.

This process resembles the last in that resin is dissolved in tar oil, but instead of adding lye the inventor adds formaldehyde.

The wood is first subjected to a high degree of heat in order to kill any organisms which may be in the wood. After creating a vacuum the impregnating solution is run in. This process is claimed to render the wood absolutely sterile at first and then to give it additional protection on the outside. As far as the original sterilization goes there seems to be no good reason for going to so much trouble. In a natural state there are no living organisms in the wood, and consequently they can not be destroyed. Decay "at the heart," which is so often mentioned, is due to entrance of destructive growths from without, just as decay on the outside is. In living trees some fungi grow into the heart through old branches, and when the timber is cut the fungus may be on the outside of a stick. There is no evidence at hand to-day which indicates that growth of such fungi continues after death. All other rotting agencies would have to get in from without.

The reason why decay takes place at the heart and not outside is easily understood when one remembers the unequal moisture conditions in the interior and outside of cut wood.

The vulcanizing idea dealt largely with the so-called coagulation of albuminous substances, and much discussion has been waged as to its ultimate effect on the timber. Without entering into any long discussion of this question here, it may be said that dry heat up to 212° F. certainly does injure wood by causing some of the volatile products of wood fiber to escape. How far moist heat does this is as yet unsolved. It is therefore better to heat wood to such high temperatures only when absolutely necessary.

The use of resin with creosote can only be commended from a theoretical standpoint. If good creosote is used the resin addition can only add to the antiseptic elements put into the wood. The process deserves extended trial.

FERRELL PROCESS.

This is a new process recently introduced by a company in this country. It claims to inject salts of various kinds into wood (aluminum sulphate, sodium chloride, calcium chloride, etc.) by means of a modification of the old Boucherie idea. The solution is forced into the end of a stick of timber. The inventors claim that the salts penetrate all fibers thoroughly and that they can cause the union of two salts in the wood, thereby forming insoluble compounds. The process sounds very attractive, but it has had no trial up to date. One great objection is that each stick of timber must be handled separately. So far there has been no cost estimate available. As with all new methods a thorough test of the process will have to be made, for theoretical considerations alone have never proved the value of anything which is so complicated as timber preservation.

CONCLUSIONS.

The universal use of different impregnating systems in Europe has brought many of them to a high state of perfection. In England and France engineers believe that their system gives them the best results, and they use (especially in France) as much of the impregnating material as the timber will hold, saying that the extra first cost is amply paid for by increased length of life. As has been pointed out, this system, which costs from 45 to 80 cents, pays with a tie which costs from $1 to $1.40. They know that with this system of impregnation they get about thirty years' life out of their timber.

In many other countries where the price of timber is not so high cheaper systems of impregnation are in use, and will continue to be used. Zinc chloride has given good results on some lines, even if it does leach out. Copper sulphate has done so likewise. The new Hasselmann treatment gives promise of good results, and is worthy of more extended trial.

The striking features about the impregnating work as now carried on in Europe may be alluded to again here. They are:

(1) Seasoning of ties before treatment.
(2) Strict inspection of ties and chemicals used.
(3) Injection of larger amounts of chemicals than are used here.
(4) Seasoning of the treated ties before placing in track.
(5) Care in all stages of treatment.

The most important comment which can be made is that the Europeans appreciate that a treated tie is different from an untreated tie. If one goes to the trouble of treating timber, it is worth while to do it well. It is worth while to regard a treated tie as an object which needs special attention. In other words, a treated piece of timber is worth more than the same timber untreated. The mere impregnation is only one step toward longer life. Subsequent care will only enhance the value of the material. Proper seasoning, careful laying, a properly drained ballast, and proper records, all go to make timber treatment a success.

Referring briefly to the situation in the United States, one may ask how far the results obtained abroad are applicable to our conditions. With the present prices of ties and tar oil we can hardly expect to get the best results obtained in Europe. For ties costing 25 to 45 cents we can not afford to pay 60 to 80 cents for treatment. It is possible that the tar oil may be available at a reduced cost, and of as high grade, in the future. At the present time the beehive ovens in which coke is burned allow all of the products of coal distillation to escape. The demand for tar oil may become great enough to warrant condensing these volatile products.

Without the tar oil our cheap ties will have to be impregnated with one or another of the cheaper processes, which will increase the length of life sufficiently to make it pay. Those which have claim to consideration are: Zinc chloride and its modification, the Wellhouse process; the mixture of zinc chloride and tar oil; and the Hasselmann process. To these one ought to add petroleum products. Very little has yet been done in the way of making use of the vast quantities of this material for timber treatment. If some means could be found for getting petroleum or some of its products into wood, so as to keep it there, a great step forward would have been taken. The suggestion is not a new one, but, in view of the fact that recent developments have brought to light such vast quantities of oil in Texas, it may not be amiss to call attention to it anew.

We know enough by this time to say that the old-fashioned way of cutting ties and laying them in the track to rot in three or four years must be abandoned, to be replaced by a careful, systematic treatment. That timber impregnation pays when properly done can not be doubted, and careful consideration of this question is urged upon all interested in the utilization of structural timber.

REMOVAL AND DISPOSAL OF TIES.

On most European lines the ties come out of the main track very much sooner, relative to their life, than they do in this country. This is no doubt due to the greater responsibility attached to the railway managements as regards prevention of accidents. This periodical removal, which occurs every fifteen years on the English lines, has brought about a system of classification of ties fit for main running lines, those for secondary lines, those for fence posts, those for firewood. In most cases long stretches of track are renewed at one time, a practice which seems of rather doubtful wisdom as far as this country is concerned. The ties which are badly cut under the rail or where the spikes will no longer hold are used as fence posts along the right of way, or are sold to farmers. Badly broken or partially decayed ties are sold for fuel at the rate of 20 cents apiece in England. In France similar use is made of old ties, and tie fences are familiar sights along the right of way. The transfer of ties before their complete wearing out has many advantages, and will, no doubt, be practiced generally in the United States, as it is now on some lines of road. Economy will still keep many a tie, which ought to come out, in the track. The necessity for doing this will be largely done away with when an impregnating method will make one year more or less of service of small account. By this the writer does not mean to argue contrary to the maxim used by inspectors, "to find out how much sound wood is in a tie."

RECORDS.

All roads which impregnate abroad keep careful records of the treatment before, during, and after impregnation, according to the following form:

Impregnating works
at Salloch.

DAILY REPORT NO.......

Date ....190..
Weather ....
Temperature, 7 a. m.. .....

Concerning the impregnation of ties from ....

Work began [date]....................and closed [date]....................

No. of operation.	No. of ties.		Weight of five ties before and after impregnation (kilograms).						Admission of steam.	Vacuum.	Filling in of liquid.	Pressure.	Running off of liquid.	Handling of timber.	Total time of operation.		Density of $CuSO_4$ solution.	Amount of $CuSO_4$ solution added after every operation.	Remarks.
									Time of operation in minutes.						Hrs.	Min.			
1			Before																
			After																
2			Before																
			After																
3			Before																
			After																
4			Before																
			After																
5			Before																
			After																
6			Before																
			After																
7			Before																
			After																
8			Before																
			After																
9			Before																
			After																
10			Before																
			After																
11			Before																
			After																
12			Before																
			After																
Engineer in charge of works.														Together.					

Materials used.					10 kilogr. $CuSO_4$ per cu. meter correspond to a 1% solution.
Coal.	Waste.	Oi.	Old ties.	"S" pieces.	
Kilograms.			Pieces.		

The inspector of the plant,

_____ _____.

The ties are marked with dating nails (fig. 25). These are placed between the rails on top of the tie, generally in the middle of the tie. They are made of steel, covered with zinc or tin, and have the year stamped in the head. When renewals take place the date at which each tie was laid is noted, and in that way an absolutely reliable record is obtained.

Too much can not be said in favor of such a plan. The nails cost very little,[a] and when put in by the section gang the labor is very slight. The value of an accurate record of the length of life of treated timber can not be overestimated, for it is the only way in which a reliable conclusion as to the value of the impregnating method used can be obtained. Several American railroads have already adopted this plan, and it is to be hoped that it will be made a matter of universal practice before long.

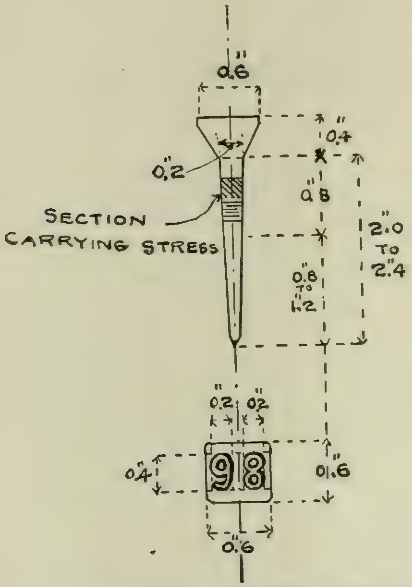

Fig. 25.—Dating nail used on French Eastern Railway.

CONCLUSIONS AND RECOMMENDATIONS.

The impregnation of timber to insure longer life has now been carried on for a hundred years or more, and yet we have not fully solved the problem. Much able work has been done on the question, but still we are far from the goal. The subject is one of the greatest complexity, and it is no doubt because of the great number of variable factors which enter into consideration that so little headway has been made. An experiment has to take into consideration all of these factors, and what the magnitude of such an experiment ought to be can be imagined by referring to some of these variable factors.

I. Timber:
  (1) Kind.
  (2) Age.
  (3) Season of cutting.
  (4) Seasoning.
  (5) Individual trees.
II. Condition of surroundings, soil, air, moisture, heat, etc.
III. Impregnating material:
  (1) Kind.
  (2) Amount used.
  (3) Method.

---

[a] Same made in the United States cost 6 cents a pound (30 nails).

As mentioned at the outset, the most attention to timber impregnation has been given by the railroads. In making the following recommendations the tie phase is emphasized particularly, because it is believed that when something is found which will increase the length of life of ties the same will apply to all other classes of structural timber. Experiments have hitherto been made largely by railway companies on their own lines. It has often been the fate of these experiments that they were begun by a man much interested in the question, who gave a good deal of time and attention to the matter. His successor took a different view of things, and all the work of the years gone by was thrown away. At the present time a general feeling is spreading that some reliable data are wanted as to what may be expected of any one or all the systems advocated. In one of the preceding chapters a plan was described which has been put into operation during the past summer. It is urged that it will be necessary to continue an experiment of this kind before reliable data will be obtained. Experiments ought to be started in several parts of the United States, where climatic and soil conditions vary, and with different timbers. The most practicable way in which results could be reached would be as follows: Every railroad or telegraph company doing any timber treatment might do so with the aid and advice of this Bureau. A central body would be able to use the practical results of all sections, and could (by having slightly additional timber treated) secure data which the individual could not obtain. It is suggested that the work of this department be extended so as to include all impregnation on all roads subject to its supervision, etc.

The questions which seem most urgent at this time may be presented in conclusion.

SEASONING OF TIMBER.

A test on a large scale should be made to determine how long different kinds of wood must be seasoned to give the best results. The different methods of piling should be investigated to demonstrate on a practical scale which gives the best results. As indicated above, it is believed that a very great saving could be obtained by giving more attention to a proper drying of timber before use.

SAWN AND HEWN TIMBER.

Probably no one of the problems discussed requires solution more urgently than that of sawn and hewn timber. This ought to be a very simple matter, in view of the fact that thousands of ties of both kinds are laid every year. When laid, the two kinds ought to be indiscriminately mixed, so as to place them under identical conditions.

FORM OF TIE.

It is recommended that ties cut according to the English system be experimented with to determine whether such a system could be used in the United States.

PRESERVATIVE PROCESSES.

As already stated, it will be desirable to test the relative value of the various preservative processes which have been shown to be of any value, and such new ones as may have appeared in the meantime. All timbers used for structural purposes should be tested. Experimental tracks should be laid in various sections of the country, with different timbers, subject to rigid scientific inspection and care by trained persons. These experimental tracks should be placed with a view of maintaining them under actual service for a long series of years. Care should be taken to make each one extensive enough to guard against the mistake of drawing conclusions from too meager data. Connected with this examination are the questions of the influence of the age of the timber to be treated, time of cutting, seasoning, etc.

CHANGES WHICH TREATED TIMBER UNDERGO.

The changes, both mechanical and chemical, which treated and untreated timber undergo in the course of time should be studied. The relative strength of treated and untreated timbers should be investigated further. The mechanical and chemical changes which the wood fibers undergo during treatment are as yet unknown. They are of the greatest importance to the engineer and architect.

UTILIZATION OF INFERIOR TIMBERS.

An examination should be made of the possibility of utilizing timbers for structural purposes which are now regarded for various reasons as unfit. The question of utilization of inferior timbers is one of the most important. The tamarack and the swamp oak are kinds of timber which few will touch to-day. They are cheap—cheaper than the sought-after pine and white oak. Their chief drawback is that they will not last. Could the larger supply of these timbers be drawn on rationally it would tend to establish an equilibrium, which would react favorably on the lumber industry, and at the same time tend to save some of those timbers more valuable for the higher kinds of structural requirements. It is therefore recommended that special attention be paid to these timbers, of which there are a number in every section of this country; that they be treated in various ways and tested as to their mechanical fitness and their lasting powers after such treatment.

THE GROWING OF TIE TIMBER.

Closely connected with this is the question of growing of timber for ties and telegraph poles in particular. In the future it will be the object to grow such timbers as will make ties and poles in the smallest number of years, and at the same time ties and poles which shall be as good and lasting as any others. The catalpa and eucalyptus timbers are without question among those which will receive more and more favorable consideration. One of the objections is their slight resisting power to mechanical stress and, in some instances, to decay. It is recommended that experiments be made in treating these timbers so as to render them more resistant in all respects.

CAUSES OF DECAY OF TIMBER.

We now know in a general way that fungi and bacteria are the agents which cause the decay of timber. There are many questions connected with their life histories which we know practically nothing of. Some of these may be pointed out—the transmission of spores from the wood to the structural material, how it takes place and how it could be prevented; the rate with which various fungi grow; the influence of soil conditions on their growth; the minimum amount of antiseptics which will prevent growth; will fungi which grow in live trees continue in wood cut from the trees, etc. It is of paramount importance that investigations be carried on to answer these questions.

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APPENDIX.

The following specifications and contracts are added as samples to show what the present practice on European lines is. The writer regrets that some of the specifications which he obtained can not be printed, because the railroads in question objected.

A general consideration of these contracts and specifications will show that the business as conducted falls into two parts—the delivery of timber and its treatment. The requirements differ in details, but in general there is considerable uniformity. The point which is most striking is the rigid inspection everywhere prevalent. That there is much to be commended in this goes without saying, and it would be well if some system of this kind were adopted wherever impregnation is carried on in this country.

EXHIBIT A.

PRUSSIAN RAILWAYS.

DESCRIPTION OF THE VARIOUS IMPREGNATING PROCESSES.

A. IMPREGNATION WITH ZINC CHLORIDE.

The impregnation is divided into three operations:

1. Steaming.
2. Establishing of a vacuum.
3. Introducing of the zinc chloride and applying of the force pump.

After the ties have been loaded on iron cars and put into impregnating tanks hermetically closed, they are subjected to the influence of steam in order to expel or render harmless the sap, which readily ferments, and also to prepare the wood for the absorption of the impregnating fluid. Besides this, by this steaming process, as much absorption as possible of the impregnating fluid should take place, to which end it is necessary that the dry surface of the ends of the ties should become softened and that the hardened gum should be removed, which runs from the ends and, combined with sand and dirt, often forms a mass impervious to fluids.

The steaming must last a longer or shorter time, according to the time of the year, the condition and kind of wood. The influx of the steam from the boiler into the impregnating tank must be managed in such a manner that the pressure of the steam in the tank will reach 1.5 atmospheres within thirty minutes.

With dry pine and oak ties it is sufficient to maintain the pressure in the impregnating tank for thirty minutes. With green pine or oak ties the duration of the steaming must be correspondingly lengthened. It will take longer for the pressure of the steam in the impregnating tank to reach 1.5 atmospheric pressure with these timbers, and therefore the pressure of the steam must be maintained for an hour longer.

Accordingly, for dry timbers the steaming lasts at least one hour, while with green timbers it must last one and one-half hours, and in some cases this period must be lengthened according to the time necessary for the pressure in the tank to reach 1.5 atmospheres. In impregnating beech timbers, whether the wood be dry or green, the steam must be continued during a period of three hours with the pressure of 1.5 atmospheres, so that it may be safely assumed that the heating of 100° C. has penetrated to the inmost heart of the wood.

A steam gauge attached to the impregnating tank will indicate the presence of the prescribed pressure.

In order to drive the air out of the tank, when the steam is first turned on a cock at the bottom of the tank must be opened until steam comes out of it. During the steaming this cock must be repeatedly opened in order to let out the water in proportion as the steam condenses. After the steaming the steam in the tank must be allowed to escape. Then a vacuum of at least 60 centimeters of mercury must be established; this vacuum must be maintained from thirty to sixty minutes, according as the wood is dry or green.

At the end of this time, in a steadily maintained vacuum, zinc chloride lye warmed to 65° or more must be forced into the impregnating tanks by means of outside atmospheric pressure until the tank is full. Then the force pump must be used in order to produce a pressure of 6⅔ atmospheres, which pressure must be maintained for at least sixty minutes, if, owing to the indications concerning the strength of the zinc chloride lye, or in order to reach the prescribed absorption of the impregnating fluid, a longer period of pressure is not required.

When this operation is completed the zinc chloride lye must be drawn off. The zinc chloride used for the impregnation must be as free as possible from foreign matter, especially surplus acid, and it must indicate a strength of 3° Beaumé at 14° R. As a regulation to make the impregnation of the wood as thorough as possible, one must determine that an air-dried railway tie of 0.106 cubic meter contents must absorb, for—

	Kilograms.	Pounds.
(*a*) Pine timber	30	65
(*b*) Oak timber	10	22
(*c*) Beech timber	30	65

And that an air-dried tie of 0.090 cubic meter content (3.1 cubic feet) must absorb at least 27 kilograms (59 pounds), while the air-dried ties, reckoning by the cubic contents, must absorb per cubic meter (35.31 cubic feet)—

	Kilograms.	Pounds per cubic foot.
(*a*) Pine timber	300	18.6
(*b*) Oak timber	100	6.2
(*c*) Beech timber	300	18.6

Should the foregoing specified absorption of impregnating fluid not be possible by the prescribed process, because the wood to be impregnated is green, or exceptionally knotty wood is to be impregnated, then the zinc chloride lye must be so strengthened that the absorption of zinc chloride free from water shall correspond with the amount of lye 3° Beaumé strong which is contained in the specified amount.

Thence it follows, that if, e. g., only 200 kilograms can be absorbed by 1 cubic meter of pine wood (1.2 pounds per cubic foot), the zinc chloride lye used must be 4½° B. strong. The samples necessary for the testing of the zinc chloride must be drawn from the outflow from the safety valve. If, according to a sample drawn, it should be necessary to strengthen the lye with concentrated zinc chloride, then it must be determined by the regulation that the specified lye has been present in the tank for half an hour. The amount of impregnating fluid absorbed by the timbers must be ascertained by weighing all the timbers directly before and after impregnating, the difference in the weight showing the amount of impregnating fluid absorbed. For the amount of zinc chloride found lacking, a deduction will be made of 15 kreutzers per 10 kilograms of zinc chloride lye of 3° B.

B.—IMPREGNATION WITH ZINC CHLORIDE MIXED WITH COAL-TAR OIL CONTAINING CARBOLIC ACID.

The treatment is carried out in just the same manner as is specified for the process with pure zinc chloride: all the specifications given for this process remain the same. In addition, while the zinc chloride is being heated, the following amount of coal-tar oil containing from 20 to 25 per cent creosote (i. e., carbolic acid) is added: 2 kilograms (4 pounds 6 ounces) for each tie, or, in other words, 20 kilograms for every cubic meter of timber.[a]

The proportion of acid oils (creosote, in other words, carbolic acid) will be shown by their solubility in sodium hydrate of 1.15 specific gravity.

The mixing of the coal-tar oil with the zinc chloride must take place by means of a good mixing apparatus and under an influx of steam.

C.—IMPREGNATION WITH COAL TAR CONTAINING CARBOLIC ACID.

The impregnation consists in three operations:

(1) The drying and heating of the ties to 110° C., in a drying oven or in the impregnating tank.

(2) The establishing of a vacuum.

(3) Running in and forcing in of the coal-tar oil by means of the force pump.

(I) Method of impregnation, using the drying oven:

First the ties must be brought on iron cars to a well-constructed drying oven, and then subjected to a heat, gradually increasing to 110° C., and dried for at least eight hours until no steam escapes and the wood has been evenly heated throughout. After the drying, the ties, while still warm, must be carried immediately on the same cars to the iron impregnating tank, which must be thereupon hermetically closed.

Then a vacuum of at least 60 cm. of mercury must be established within the impregnating tank. This vacuum must be created after the expiration of thirty minutes at most and maintained for thirty minutes longer.

At the end of this time, with continuous application of the air pump, the tank must be filled with the coal-tar oil containing creosote, which must be previously warmed indirectly by steam pipes in basins or a tank to 45° to 60° C.

(II) Method of impregnation, using hot solution:

In case the heating should take place in the impregnating tank, the ties and timbers to be impregnated must be brought directly to the impregnating tank, which must be hermetically closed.

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[a] 1 meter = 39.37 inches.
1 kilogram = 2 pounds 3 ounces.
1 cubic meter = 35.31 cubic feet.

Then a vacuum of at least 60 cm. of mercury must be created in the tank filled with timber, and the impregnating oil, previously heated to about 60° C., or more, must be run in in the presence of a continued vacuum.

During and after the filling, the coal-tar oil in the impregnating tank must be warmed to 105°, in some cases 110° C., indirectly, by means of steam, either by a system of pipes lying in the lower part of the tank, or by a cylinder arranged under the same. This temperature of the impregnating oil must be reached within three hours and then maintained for a full hour longer.

Should the temperature of 105° not be reached within three hours, then the duration of the heating must be lengthened until 105° C. is reached. From this point the impregnating of the wood will be carried on in the same manner, whether the wood has been heated in a drying oven or in a tank.

Now, by use of the pump, a pressure must be produced at least 6⅔ atmospheres more than the outer atmospheric pressure; this pressure must be maintained for at least sixty minutes longer, if a lengthening of the duration of the pressure is not necessary to induce the specified absorption of the impregnating fluid.

The oil produced from coal tar must contain only a minimum of easily volatilized elements; the oils must be so heavy, that, determining by the greatest part, the boiling point between 180° C. and 400° C. will lie beyond 235° C.

The proportion of acid elements (creosote, i. e., carbolic acid) soluble in concentrated alkaline lye must amount to at least 10 per cent. In spite of the high boiling point, the oil must be thinly fluid and sufficiently free from solid elements to penetrate immediately when poured on dry crosscut timber, and to leave no other residue than that mentioned above. At the same time the oil must be sufficiently dense to be retained as completely as possible in the pores of the wood after the treatment. It must contain no oils, or at most 3 per cent of oils having a specific gravity of the oil, and must not amount to more than 1.10. At most 25 per cent of other oils produced from wood coal, peat, and wood may be mixed with the coal-tar oil, if the former oils answer satisfactorily in the specified properties to the coal-tar oil.

The contractor guarantees that the average amount of creosote, or, in other words, tar oil containing carbolic acid, absorbed by each air-dried pine or beech railway tie of the larger sort, of 0.104 cubic meter (3.67 cubic feet) contents, shall be at least 20 kilograms (23.6 pounds), and that absorbed by ties of the smaller kind, of 0.090 to 0.083 cubic meter contents, shall be at least 18 kilograms, and that absorbed by each air-dried oak railway tie at least 8.5 kilograms (18.5 pounds), and the amount absorbed by timbers which are reckoned by the cubic contents shall be—

	Kilograms.	Pounds per cubic foot.
Per cubic meter of pine and beech timber	200	12.4
Per cubic meter of oak wood	85	5.2

The amount of coal tar absorbed by the timbers must be ascertained in the following manner: All the timbers must be weighed, after the drying in the drying oven, or, if the timbers are not put in the drying oven, before the treatment in the impregnating tank, and for a second time after the impregnation.

For the amount of coal tar found wanting by the method stated above a deduction of 6 florins (Austrian) per 100 kilograms will be made. If the amount of oil found wanting is more than one-sixth of the specified amount to be absorbed, then the impregnation must be repeated.

EXHIBIT B.

BAVARIAN STATE RAILWAYS.

EXTRACT FROM SPECIFICATIONS FOR IMPREGNATING FIR RAILWAY TIES WITH ZINC CHLORIDE MIXED WITH COAL TAR CONTAINING CARBOLIC ACID.

1.

[Omitted.]

2.

The impregnating process is divided into three parts:

(1) The steaming of the ties.

(2) The establishing of a vacuum and the introducing of the impregnating fluid into the tank.

(3) The forcing in of the impregnating fluid by the use of the force pump.

3. *Steaming of the ties.*

The ties must be loaded on iron cars, put into the impregnating tank, and, after the latter has been hermetically closed, the ties must be heated by having steam turned into the tank. This should make the wood fit for absorption, cleanse it, and soften and remove the gum mixed with sand and dirt adhering, especially to the ends.

According to the season and the condition of the ties, the steaming must be continued for a longer or shorter period.

The influx of the steam must be so conducted that the steam gauge connected with the impregnating tank will indicate a pressure of 1½ atmospheres after, at most, thirty minutes.

Dry wood must be subjected to this steam pressure for thirty minutes longer, green wood for sixty minutes longer; so that the steaming of dry ties will last for at least one hour, of green ties at least one and one-half hours.

With the influx of the steam the air in the impregnating tank will be expelled by the opening of a crack in the lower part of the tank. During the steaming this crack must be opened repeatedly in order to let out the water by degrees as the steam condenses; but this must be done every half hour at least, and for the last time immediately before the air is pumped out.

After the wood has been treated with steam for a sufficiently long period the steam must be drawn off from the impregnating tank.

4. *The establishing of the vacuum and the pouring in of the impregnating fluid.*

After the steam has been drawn off, a vacuum of 600 mm. (23½ inches) of mercury by the vacuum meter must be established in the impregnating tank filled with ties, and this vacuum must be maintained for ten minutes.

At the end of this time, without reducing the vacuum, the impregnating fluid, which must be previously put in a special tank and heated to at least 65° Celsius, must be turned into the tank.

The impregnating fluid is produced by adding to the zinc chloride solution, while it is being heated, 1 kg. of tar oil to every 10.76 kg. of zinc chloride (i. e., 9.2 pounds of tar oil to every 100 pounds of zinc chloride). Accordingly, every tie 2.7 m. (8.85 feet) long requires 3 kg. (6 pounds 9 ounces) of tar oil. In order that the mixing may be as complete as possible, proper arrangements must be made for mixing the fluids in the presence of steam and air.

5. *The forcing in of the impregnating fluid by means of a force pump.*

After the tank has been completely filled the impregnating fluid must be forced into the wood by means of a pump, the pressure being raised to at least 7 atmospheres.

That the saturation of the wood may be as complete as possible, this pressure must be maintained for at least thirty minutes, and, if it is necessary, the time must be lengthened until the specified amount of impregnating fluid has been absorbed.

This completes the impregnating of the wood, after which the fluid must be drawn off.

Suitable distilling apparatus must be ready for the removal of any impurities in the impregnating fluid brought about during the treatment.

6. *Composition of the impregnating fluid.*

a. Zinc-chloride solution:

This must be as free as possible from impurities and especially free from free acids.

The solution must have a strength of 3.5° Beaumé—1.0244 specific gravity at 15° Celsius.

The proportion of metallic zinc in this solution amounts to 1.26 parts.

It will be admissible to mix in only the very least traces of other metals, especially iron, and only in so far as they can not be avoided in the manufacture.

b. Tar oil:

This tar oil must be so composed that by distillation to 150° Celsius, at most 3 per cent, from 150–235° Celsius, at most 30 per cent, and from 150–355° Celsius about 85 per cent is distilled over. The specific gravity at 15° Celsius should be between 1.03 and 1.10. At 20° Celsius the oil should be so clear that a few drops poured on filter paper folded several times will be entirely absorbed without leaving more than a trace of undissolved solid elements. The proportion of acid elements (like carbolic acid), that is, elements soluble at 15° Celsius in sodium hydrate, specific gravity 1.15, must amount to at least 10 per cent.

7. *Guarantee of the absorption of impregnating fluid.*

It is guaranteed that the average absorption of impregnating fluid for every full tank considered must amount to 35 kg. (76 pounds) for a fir railway tie 2.7 m. long and 16 cm. by 26 cm. cross section (8 feet 10 inches by 6.2 inches by 10.2 inches).

To ascertain the amount of impregnating fluid taken up by the ties, a float must be fixed in the reservoir from which this fluid is run into the tank, with a legible scale above the reservoir. This scale must be graduated according to the ground plan of the reservoir, with the assumption that the fluid has a medium specific gravity of 1.02 according to each 100 kg. (220 pounds). At the beginning of the absorption the reservoir must be quite full. At the end of the impregnating, i. e., when the impregnating fluid has all run back into the reservoir, the depth of the fluid in the reservoir will be shown on the scale. The difference between this depth and the depth when the reservoir was full will give in kilograms the fluid absorbed.

If, as ascertained above, less than the specified amount of impregnating fluid should be absorbed, a deduction in money of fifteen pfennig will be made for every 10 kg. (16 cents per 100 pounds) lacking; but if the absorption should be less than five-sixths of the specified amount, the impregnation must be repeated without any extra charge.

8. *Superintendence of the impregnation.*

In each case, eight days before beginning the treatment of the ties, the contractor must send a notification stating the source of the zinc chloride solution and of the coal-tar oil, so that an agent of the K. B. State Railway may be sent in time to superintend the work.

The agent must at any time be free to enter all the working rooms of the contractor; all desired information must be given him readily, and all implements, materials, and means to assist his work, necessary to carry out his office, must be put at his disposal. His instructions must be accurately followed.

This agent must ascertain that the impregnating apparatus is fit for the use to which it is to be put and that the instructions for impregnating are exactly followed. He will accept the ties impregnated according to the specifications. He will take samples of the fluid and of the wood for chemical analysis, and he will have remedied any deficiencies he may find.

The railway company has the right to have a chemical analysis of the impregnating fluid made at any time and at the cost of the contractor.

9. *Impregnating journal.*

The contractor must keep a journal in which are carefully recorded the several processes of the impregnation, the number of ties impregnated, the beginning and end of the impregnation, information concerning the amount of impregnating fluid absorbed by the ties, and also the strict observation of the various specifications. This journal must always be open to the registering agent for inspection.

Exhibit C.

Method of Impregnating Railroad Ties as Applied in the Imperial Impregnating Works at Kircheson, Bavaria.

I.—*Impregnation of ties in general.*

All ties are impregnated with zinc chloride in order to increase their durability. This method of preparing wood consists in steaming it in order to dissolve the more or less dried substances in the wood fiber which induce decay. This fluid is then expelled from the wood as completely as possible by means of air pumps, and antiseptic fluids are forced into the wood. The albumen remaining in the wood cells is congealed and also all substances capable of fermenting.

A weak solution of water and neutral zinc chloride is forced into the wood by a pressure of about eight atmospheres, in order to reach every possible part of the wood, to prevent decay.

II.—*Particulars.*

The method of impregnating the ties, which are to be without bark, is as follows:

In order to convey the ties as quickly and as cheaply as possible to the wrought-iron cylinder, the wood is stacked as near the workshop as possible and carried from there to the workshop by means of small cars on narrow-gauge tracks. The most advantageous means of conveying the wood in and out of the cylinder is by loading it onto an iron car. While the wood is going through the process in the cylinder it rests on iron tracks that are fastened to the cylinder.

When, as an exception, single pieces of wood are put into the cylinder, care must be taken to avoid contact with the pipes in the bottom of the cylinder which are to carry off the fluids from the wood and convey zinc chloride and the like. After the cylinder is filled with wood it must be sealed air-tight by means of the door of the cylinder, which is fastened with bolts and screws. In order to seal the cylinder completely an air-tight substance must be put between the top of the cylinder and the inner edge of the cover.

This is accomplished by means of an iron ring whose cross section is $\frac{0035}{0.004}$. Long strips of linen must be wound around the ring until it is pretty thickly covered, and then the whole is saturated with tallow. Tallow must be applied to the ring each time before wood is placed in the cylinder, but at all other times the ring must be in its place.

III.

While the wood is being brought in and the closing of the cylinder is taking place. the cylinder is heated and sealed. Then steam of 5 to 6 kg. (11 to 13 pounds) is admitted. After steam has been pouring into the vat for thirty minutes the waste faucet at the bottom of the cylinder, for drawing off the wood fluids, must be opened until steam pours out. This process must be repeated from two to three times. The time of steaming ties that are not completely dry, with highest pressure of steam, is about three hours. The pressure of steam in the cylinder at the end of the steaming must be at least one-half atmosphere for fifteen minutes. After the steaming the steam faucet is checked and the refuse faucet is opened to draw off the wood fluids. This faucet is left open until the escaping steam emits no sound.

IV.

After this process all steam and air must be forced from the cylinder by means of an air pump. Steam vacuum pumps are applied until the air in the cylinder has reached 550 mm. (21½ inches) by the barometer. This is quite possible with an apparatus in good condition. But since not only the air in the cylinder and the steam about the wood must be removed. but also the fluids that come from the wood, this work must continue at least one hour more, and if the work of preparing the wood be not too pressing even two hours would be advantageous.

V.

After this has been completed, the solution of zinc chloride is allowed to flow into the cylinder. The air pump continues to operate during all this time. The zinc chloride rises rapidly in the cylinder. The height to which the fluid has risen can be determined by placing the hand on the cylinder, since the cold chloride cools its sides, which are still hot from the steam. A register attached to the side of the cylinder is a more exact means for ascertaining the height of the chloride.

The air pumps remain in action until they begin to pump out the preparing fluid.

VI.

After the cylinder had been filled with the solution of zinc chloride and the air pumps have ceased their work, the pipes admitting the chloride are checked, though the force pumps are brought into action and the valve at the top of the preparing cylinder is opened, and thus the air left in the preparing cylinder is expelled.

When the cylinder is so filled with the chloride that it runs over through the valve, then the valve is closed. The force pumps continue to work for about three-quarters of an hour, the pressure reached at this time being about 8½ atmospheres. This pressure must continue in action for the entire time, but the pumping may be slowed up gradually.

The fluid being forced into the wood lessens the pressure, and for this reason the pumping must continue during the entire process. With oak wood, a pressure of 8½ atmospheres can be reached in ten minutes, because oak absorbs little fluid; with pine wood fifteen minutes are needed, and with fir forty minutes; beech wood takes fifty minutes.

VII.

After the necessary time allowed for the fluid to affect the wood has elapsed, the air valve is opened, and the fluid which has not been absorbed is returned to the reservoir from which it was drawn. Then the cover is taken off the treating cylinder and the wood is lifted out and carried away to be stacked up. After this the preparing cylinder is thoroughly cleansed and the sediment at the bottom removed. Then the process is repeated exactly as described above with the next batch of wood. For this whole process, from the carrying in of the wood to the carrying out of the impregnated ties, the method of procedure is written out and posted for the workmen who follow it in every detail.

VIII.

The entire time occupied by the process is eight hours for ties not entirely dry and six hours for entirely dry ones.

The scheme for impregnation posted in the workshop is to be referred to often and to be followed by the workmen in every detail under the most careful supervision of the man in charge.

IX.—*The preparation of the impregnating fluid.*

The chloride of zinc used must be neither acid nor base, but neutral. It is to have a specific weight of 1.60 to 1.50.

The impregnating fluid is made up of 1 part chloride of zinc to 49 parts of water, and contains 0.66 per cent zinc, 0.72 per cent chloride, and 98.62 per cent water.

In testing the chemicals special care is to be taken to make sure that zinc and chloride are in the above-prescribed proportion. But since zinc chloride can not be procured in an absolutely pure state in great quantities, therefore it is not demanded that the substance be chemically pure. The presence of other metals in small quantities, particularly iron, does no harm, since these foreign substances of the combination are also soluble in water and have the same antiseptic properties. In case the solution of zinc chloride is kept a long time the particles of the combination separate into zinc sulphate and other basic salts and thus change the composition of the zinc chloride. For this reason it is necessary to dissolve the salt sediment in a proportional quantity of acid in order to bring about a regeneration of zinc chloride. A surplus quantity of acid is to be avoided. This can be accomplished by the introduction of raw zinc. The quantity of chloride of zinc contained in the fluid, which is to be used continually and regenerated as it becomes necessary, does not stay the same. The exact proportion can not be ascertained exactly, since the fluid becomes heavier by the unavoidable addition of wood saps and other impurities and, on the other hand, lighter by the loss of the above-mentioned sediments. The water used at Kiercheson, even when the fluid is kept for months, has no detrimental effect upon the solution. This variable impregnating fluid must be tested at least once a month and oftener, if necessary, for the purpose of seeing that the solution contains the proper quantity of zinc chloride, and when found lacking to improve it.

Moreover, it is required to examine the apparatus from time to time in all its parts in order to make sure of its efficiency. To this end the supervisor must examine the prepared ties in order to see whether the zinc chloride has thoroughly penetrated. If this is not the case, the matter must be looked into at once, the source of trouble discovered, and the matter remedied.

Exhibit D.

French Eastern Railway.

SPECIFICATIONS CONCERNING THE SUPPLY OF OAK TIES.

Article 1.—*The nature of the wood and its origin.*

The ties shall be of the best quality of oak wood. All wood must be rejected which has grown on damp fertile ground, or which was not felled at the proper season.

The wood must be taken from such places as are indicated in the agreement; the engineer of the company shall have the right to exclude wood from other sources whose quality seems inferior to him.

Article 2.—*Shape of ties.*

The ties shall be cut square; the upper and under surface must be dressed with a saw; the lateral surfaces may be hewn with an ax.

The under side, which rests on the roadbed, must have sharp, angular edges. On the opposite side the good wood must be on top, exposing a surface of at least five centimeters ($0^{m}.05=2$ inches) on either side of the middle of the tie, in the place where the groove extends toward each end, for a distance of from fifty centimeters ($0^{m}.50=19.7$ inches) to one meter ($1^{m}.00=39.37$ inches) from the middle of the length, as a starting point. (The parts marked with cross lines, as shown in the above sketch, indicate the minimum of good wood, required to be exposed, on the upper surface of the tie.) Imperfections may be tolerated on this upper surface if they do not measure more than five centimeters ($0^{m}.05=2$ inches), as is indicated in the cross sections below.

Article 3.—*Dimensions of the ties.*

The ties shall be from two meters sixty centimeters ($2^{m}.60=8$ feet 6 inches) to two meters seventy centimeters ($2^{m}.70=8.85$ feet) in length. Their thickness shall be between fourteen and fifteen centimeters ($0^{m}.14=5.5$ inches; $0^{m}.15=5.9$ inches).

The width may vary from twenty-two ($0^{m}.22=8.66$ inches) to twenty-five centimeters ($0^{m}.25=9.8$ inches).

Article 4.—*Curvature of the wood; of the ends.*

The upper and under surfaces must be perfectly level and parallel. As for the lateral surfaces a curvature whose angle of inclination does not exceed ten centimetres ($0^{m}.10=3.937$ inches) is allowed.

The ends of all the ties shall be finished with a section perpendicular to the length.

Article 5.—*Quality of the wood.*

The ties must be perfectly healthy and of straight grain; they must be free from decay, bad knots, twists, frost clefts, stings, double bark, and whatsoever imperfections there may be. The bad wood, as well as that which has its inner bark in bad condition, shall be refused.

Article 6.—*The delivery and measurement of the wood.*

The ties shall be delivered at those depots indicated in the contract and at the time agreed upon, in batches of not less than 200 pieces per station. Orders demanding less than 200 pieces shall be filled in one shipment. The ties shall be examined and measured with the greatest care by an agent of the company, in the presence of the contractor or his agent, and the dimensions shall be immediately written on the bill of lading, which the agent of the company must sign, before the wood is finally given over by the contractor. The measuring shall be done with 5 centimetres (2 inches) as a unit of measure for the lengths and 1 centimetre (0.39 inch) for the widths and thicknesses. The latter are to be measured in the narrowest parts. All fractional parts of 5 centimetres (2 inches) or of 1 centimetre (0.39 inch) in measuring lengths and widths and thicknesses, respectively, shall not be counted. The average cube is not to be less than the cube which is the result of the average of the upper and lower surfaces. In case it is less, the price stipulated in the contract shall be reduced in the proportion in which the actual cube stands to the required cube. In case of excess the contractor shall be granted no increase in price.

All the pieces which have one, or better two or three, dimensions that do not come up to the minimum requirements as stated in article 3 shall be refused. The pieces whose dimensions exceed those indicated as maximum requirements may be accepted, but no account is to be taken of the excess. The ties that have been accepted shall be stamped with the trade-mark of the company.

The ties that have been refused must be removed from the depot by the contractor after each delivery. The bill of lading shall not be returned to the contractor after the receipt of goods until all the refused ties have been cleared away.

ARTICLE 7.—*Charges and stacking of ties.*

All expenses of transport, loading and unloading, and all hand labor involved in the delivery shall be at the cost of the contractor.

The ties after they have been accepted shall be loaded onto wagons, if the company can put them at the disposal of the contractor, immediately after delivery. If this is not the case the ties are to be stacked up in regular piles in the places meant for this, and it shall not be required of the contractor to attend to the loading. The contractor shall guarantee to be held responsible for all claims of damage done neighboring roads or the forests owned by the company or other ownership.

ARTICLE 8.

It is the object of these resolutions concerning the charges to forbid the selling of any part whatsoever of the supply without the written consent of the company.

RESOLUTIONS CONCERNING THE REQUIREMENTS OF THE SUPPLY OF OAK WOOD FOR CHANGES AND ROAD CROSSINGS.

ARTICLE 1.—*Object of these resolutions.*

These resolutions have for their object the supply of ties destined to the establishment of machinery for changes and crossings in the road.

ARTICLE 2.—*Kind of wood and its source.*

The wood shall be of the best quality of oak wood. The wood which has been grown in damp fertile lands and has not been felled at the right time shall be refused. The wood must be taken from such lands as are indicated in the contract. The engineer of the company shall have the right to reject wood of other source, whose quality seems to him to be inferior.

ARTICLE 3.

The ties shall be square, the upper and lower surfaces shall be dressed with a saw, and the lateral surfaces may be hewn with an ax. The lower side shall have sharp angular edges without bark. Imperfections shall be tolerated on the opposite surface, that is if they do not measure more than 5 centimetres (2 inches).

ARTICLE 4.—*Dimensions of the ties.*

The normal dimensions of the ties shall be indicated in a picture accompanying the contract.

The following exceptions shall be added to the normal dimensions:

(1) For the lengths, 10 centimetres ($0^{m}.10=3.937$ inches), more or less.

(2) For the widths, 1 centimetre ($0^{m}.01=0.39$ inch), more or less.

(3) For the thicknesses of 15 centimetres ($0^{m}.15=5.9$ inches) and above, 1 centimetre ($0^{m}.01=0.39$ inch) more or less.

The company besides may order ties purposed for extraordinary machinery, whose dimensions shall be indicated during the course of the work. Their ——— shall be restricted to the limits of the picture, and their cube shall not exceed the twentieth of the total supply.

The upper and under surfaces shall be perfectly level and parallel. In the sides a curvature, whose angle of inclination shall not exceed 1 centimetre (0.39 inch) in a length of 1 metre (39.37 inches) (that is one one-hundredth of the total length of the piece of wood). The ends shall all be finished off by a cross-section perpendicular to the length.

ARTICLE 5.—*Quality of the wood.*

All the pieces must be perfectly healthy and of straight grain; they must be free from decay, bad knots, twists, frost clefts, stings, double bark and cracks, and whatever other imperfections there may be; also the wood whose inner bark has deteriorated shall be refused.

ARTICLE 6.—*The delivery and measurement of the wood.*

The ties shall be delivered at those depots indicated in the contract and at the time agreed upon. They shall be examined and measured with the greatest care, by an agent of the company, in the presence of the contractor or his agent, and the dimensions shall be noted down immediately on the bill of lading, which the agent of the company must sign in order to accept the wood.

The pieces shall be marked with the letters of the trade-mark indicated in the picture accompanying the contract.

The measurement shall be made with a unit of 5 centimetres (2 inches) for the lengths and of 1 centimetre (0.39 inch) for the widths and thicknesses, the last being measured where the wood is narrowest. All fractional parts of 5 centimeter (2 inches) in the lengths and of 1 centimeter (0.39 inch) in the widths and thicknesses, shall not be counted.

All the pieces which have one, or better two, dimensions that do not come up to the minimum requirements in article 4, shall be rejected. The pieces whose dimensions exceed those indicated as maximum requirements may be accepted, but without taking the excess into account.

The ties that have been accepted shall be stamped with the trade-mark of the company.

The ties that have been refused must be removed from the depot by the contractor after each delivery. The bill of lading shall not be returned to the contractor after the receipt of the goods until all the refused ties have been cleared away.

ARTICLE 7.—*Charges of the contractor.*

All the expenses of transportation, loading, and unloading, and all hand labor involved, shall be at the cost of the contractor. The wood received at the stations indicated in the contract shall be stacked up with care by the contractor, on the place designed for this purpose. The contractor shall guarantee to be held responsible for all claims of damage done the neighboring roads and forests, owned by the company or of other ownership.

RESOLUTIONS FOR THE SUPPLY OF BEECH-WOOD TIES.

ARTICLE 1.—*Kind of wood and source of supply.*

The ties shall be of beech wood. All wood that was not felled between October 1st and March 1st, and that was not delivered before the 1st of June, shall be refused. The wood shall be gotten from those places indicated in the contract. The engineer of the company shall have the right to exclude wood of other source which seems to him to be of inferior quality.

ARTICLE 2.

The ties shall be square. The upper and lower surfaces shall be dressed with a saw; the sides may be hewn with an ax.

The under side, which rests on the roadbed, shall have sharp, angular edges.

Imperfections shall be allowable on the opposite surface, if they do not measure more than 5 centimeters ($0^{m}.05=2$ inches). Ties with three sawed surfaces and one rounded one, as well as ties with two parallel sawed surfaces, shall be accepted as square. All beech ties shall be completely stripped of their bark.

ARTICLE 3.—*Dimensions of the ties.*

All ties have for their length: From 2 metres 60 centimetres ($2^{m}.60-8.53$ feet) to 2 metres 70 centimetres ($2^{m}.70=8.85$ feet).

Their thickness shall be: From 14 centimetres ($0^{m}.14=5.5$ inches) to 16 centimeters ($0^{m}.16=6.3$ inches). Their width shall be: From 23 centimetres ($0^{m}.23=9.05$ inches) to 26 centimetres ($0^{m}.26=10.24$ inches).

The ends of all ties shall be finished off with a cross-section perpendicular to the length.

ARTICLE 4.—*The quality of the wood.*

The ties shall be of perfectly straight grain. The wood shall be free from decay; the inner wood must neither be red nor grey; the wood must be free from bad knots, twists, frost clefts, stings, and all other blemishes.

All wood that is defective shall be absolutely refused, and the agents of the company shall be allowed to use all possible means of control which they deem necessary in order to make sure that the wood shall be free from these faults.

ARTICLE 5.—*The provisionary delivery and the measurement.*

The ties shall be delivered at the depots indicated in the contract and at the time agreed upon, in batches of not less than 200 pieces per station. All orders demanding less than 200 pieces shall be filled in one shipment.

They shall be examined and measured with the greatest care by the agents of the company, in the presence of the contractor, and the dimensions of each tie shall be written on the bill of lading, which shall be signed before the goods have been finally accepted. The measurements shall be taken with 5 centimetres (2 inches) as a unit of measure for the lengths and 1 centimetre (0.39 inch) for the widths and thicknesses. The last two dimensions shall be measured in the narrowest part of the wood. All fractional parts of 5 centimetres (2 inches) in the lengths and of 1 centimetre (0.39 inch) in the thicknesses and widths shall not be counted. The average cube of the ties shall not be less than the cube which is the result of the average of the upper and lower dimensions. In case it is not large enough, the price stipulated in the contract shall be reduced in the proportion in which the actual cube stands to the required cube.

All pieces which have one, or, better, two or three dimensions that do not come up to the minimum requirements as stated in article 4 shall be refused. Those pieces whose dimensions exceed the measurements of the maximum requirements may be accepted, but without taking any account of the excess. The ties that have been accepted shall be stamped at both ends with the trade-mark of the company.

The ties which have been refused shall be removed from the depots by the contractor after each delivery. The bill of lading shall not be returned to the contractor until all the refused ties have been cleared away.

ARTICLE 6.

All expedients which the agents think necessary in order to insure the quality of the wood, all expenses of transportation, all hand labor involved in delivery, and loading and unloading shall be charged to the contractor.

The ties which have been accepted shall be piled up by the contractor at his own expense. The stacking shall be done in regular piles and with all precautions necessary to insure the preservation of the wood.

It is the object of these resolutions to forbid absolutely the selling of any part of the supply without the written consent of the company.

EXHIBIT E.

TESTING OF IMPREGNATING SOLUTIONS FOR IMPERIAL PRUSSIAN RAILWAYS.

For the impregnation of timber there are at present two products in use: 1st, chloride of zinc; 2d, tar oil.

TESTING OF CHLORIDE OF ZINC.

The chloride of zinc for impregnating purposes will be manufactured as a concentrated solution, containing about 50 per cent of anhydrous chloride of zinc. It is best to use such a strong solution for testing, and for that purpose samples are to be taken directly from the shipping tank or carboy.

The zinc chloride solution used must be as free from impurities as possible, particularly from iron and free acid. Therefore it is to be determined whether or not iron and acid are present.

TEST FOR FREE ACID.

Twenty grammes (by weight) of the above strong zinc chloride solution are to be mixed with distilled water; the whole to amount to 100 cu. cm. (by measure), the mixture to be well shaken.

(*a*) There is no free acid present if the mixture by shaking becomes cloudy, and particularly if, after a short period of rest, flakes settle down which will again dissolve to a clear fluid upon the addition of a few drops of muriatic acid (HCl). No further test is then required.

(*b*) If after shaking the mixture remains clear, then an excess of acid is present, the amount of which can be determined by the following manipulation:

Take several reagent bottles and put in each 10 cu. cm. of the above-described mixture; then add to each bottle a measured successively increasing quantity of a solution of one-tenth normal soda. For example: Add to the first reagent bottle 0.1 cu. cm.; to the second, 0.2 cu. cm.; to the third, 0.4 cu. cm., and so on. Shake well and observe in which bottle a remaining white, flaky precipitation will settle. The proportion of soda which lies between the mixture where a precipitation is produced and that where no precipitation is produced exactly represents the quantity of free acid present in the solution. For example, the mixture in the bottle to which 0.2 cu. cm. of the soda solution was added remains clear, while in the following reagent bottle, where 0.4 cu. cm. soda solution was added, a precipitation is produced, then 0.3 cu. cm. soda solution is exactly the quantity corresponding to the free acid present in the chloride of zinc solution.

Should there be required for this test more than 0.4 cu. cm. of the one-tenth normal soda solution, then the percentage of free acid is too high in the chloride of zinc solution, and such solution must not be used for impregnation.

TESTING FOR IRON.

Take 10 cu. cm. from the above-described mixture of zinc chloride solution and distilled water, and add a few drops of concentrated nitric acid (HNO_3) and shake well. Divide this mixture into two equal parts. To one part, without diluting, add a quantity of ammonia (NH_4OH) and shake well. If this mixture remains clear, no iron is present. Through the presence of iron in the mixture, more or less brown flakes will precipitate, corresponding to the amount of iron present. Should there precipitate in the mixture a quantity of gray-white (not brown) flakes, then not only iron, but also another impurity (nearly always magnesia) is present. In this latter case a more complete test has to be made, and therefore the zinc chloride solution must be sent to a chemist. But this case will happen very seldom.

The second part of the mixture of 10 cu. cm. to which nitric acid was added, should be diluted with distilled water, and 5 cu. cm. of a solution of 10 per cent yellow prussiate of potash added, the whole to be well shaken. A very ample precipitation will be produced, which will look snow white or very light yellowish if the zinc chloride solution is free from iron; but in the presence of iron it will look more or less blue, according to the amount of iron. If the precipitation shows a corn-flower-blue color, then the zinc chloride solution surely contains a high percentage of iron and must therefore be rejected.

To avoid, in testing, the weighing of the 20 grammes of the strong solution, the use is recommended of the easier method of measuring. First find the specific gravity, at 15° Celsius, of the strong concentrated zinc chloride solution. The quotient of this specific gravity into 20 grammes shows the number of cubic centimeters which must be measured off and which represent exactly 20 grammes by weight. For instance, the specific gravity of the strong zinc chloride solution is 1.6, then 1.6 divided into 20 grammes gives the number of cubic centimeters $\left(\frac{20}{1.6} = 12.5 \text{ cu. cm.}\right)$ which have to be measured off to be used for testing as described above.

TESTING OF TAR OIL.

At a temperature of 20° Celsius the tar oil must be limpid, and to test it shake the tar oil well, pour a few drops on a folded filter paper, and observe whether after absorption there remain undissolved particles on top of the paper. If the amount of these is large, the tar oil must not be used for impregnation. To find the specific gravity, the tar oil must be heated, or cooled off, to a temperature of 15° Celsius; then drop slowly an hydrometer into the same, and read the number at the surface of the oil. This number indicates the specific gravity of the tar oil at 15° Celsius; small variations in temperature are of minor importance, and can be corrected closely enough by adding or substracting 3 to the figure in the third place of the specific gravity for every 2° variation from 15° Celsius.

LABORATORY DISTILLATION OF THE TAR OIL.

By means of a funnel, 102 cu. cm. of tar oil at about 15° Celsius are to be filled into a retort, a thermometer is to be inserted, but in such a manner that the quicksilver ball shall be in or below the neck of the retort but shall not touch the oil, or will not be covered by the same. The retort must be heated slowly, until all the water, which is contained in nearly every tar oil, is evaporated. Stronger heat can then be applied to the retort, but it must be so regulated that in one second two drops will distill over. The distilled product will be caught in a graduated glass cylinder, and the different quantities are to be read and noted which distill over from the oil (become volatile), within the various intervals of temperature, say from 125° to 150° Celsius, from 150° to 235°, and again from 150° to 355° Celsius, and which are specified in the "Description of the Process and Specifications" as to the composition and proportions of the impregnating fluid.

FINDING THE PERCENTAGE OF CARBOLIC ACID (ACID CONSTITUENTS OF THE OIL).

The entire amount of the distilled tar oil is to be mixed in a separating funnel with 50 cu. cm. of caustic soda of 1.15 specific gravity at 15° Celsius, shaken well for about five minutes, after which let it stand and settle. The caustic soda absorbs the carbolic acid and precipitates; the stopcock of the funnel is to be opened and the precipitated caustic soda is caught in a 200 cu. cm. graduated glass cylinder. The same operation must also be repeated with 50 cu. cm. of fresh caustic soda, to make sure that all carbolic acid is extracted from the oil. The caustic soda of both manipulations is then to be combined, about two tablespoonfuls of salt ($NaCl$) added and this dissolved by means of stirring; the required quantity of concentrated muriatic acid (HCl) added, and the combination again stirred up until well mixed. After cooling off the hot mixture, read the quantity of the separated carbolic acid in percentage of cubic centimeters, and add to this number ½ per cent for the small amout of carbolic acid still remaining in the acid solution.

All the figures obtained are to be compared with those specified in the description of the composition and proportions of the impregnating fluids. Small differences should not be cause for rejection, as small variations in testing, resulting from barometric changes, can not be avoided, and the result of the test is influenced by them. However, the figures obtained by the above-described tests are sufficiently close to judge of the quality of the impregnating fluids. It is not advisable that the tar oil for testing be taken directly from the shipping tank, but it is better to take the samples from the receptacle of the apparatus in the impregnating plant from which the mixing vessels, or the impregnating cylinder (in the impregnation with pure oil) will be supplied.

The Chief of the Operating Inspection 3.

SETTGAST.

BERLIN, *June 14, 1899.*

EXHIBIT F.

WESTERN RAILWAY OF FRANCE—IMPREGNATION WITH CREOSOTE.

ARTICLE 7.—*Process for impregnating with creosote.*

The impregnation with creosote shall consist in the injection, by means of a vacuum and pressure, of crude creosote previously raised to a temperature between fifty and sixty degrees (50 and 60) centigrade (=112° to 140° F.).

ARTICLE 8.—*Composition of the creosote.*

The crude creosote shall be the product of the distillation of gas tar.

It shall be of the first quality and like the samples which the contractors shall give and submit to the approbation of the engineers of the company.

Creosote which does not contain at least five per cent (5%) of phenic acid may be refused.

ARTICLE 9.—*Origin of the creosote.*

The contractors shall be obliged to make known the works from which each of the supplies of creosote come.

ARTICLE 10.—*Condition of the ties before impregnated with creosote.*

The ties to be impregnated must be very dry, and they shall be previously notched by the contractors at the expense of the company, to receive the chairs or Vignoles rails.

That the wood is quite dry shall be assured by weighing a certain number of ties taken at random. The weight of the wood thus ascertained shall not be over eight hundred and fifty kilograms (850 kg.=1,874 pounds) per cubic meter (1.308 cubic yards) for the oak, and seven hundred and fifty kilograms (750 kg.=1,653 pounds) per cubic meter for the beech.

ARTICLE 11.—*Impregnation with creosote.*

The ties to be impregnated shall be placed in a sheet-iron cylinder. After having closed the cylinder filled with ties, a vacuum shall be made within. This vacuum shall be carried to a pressure of $0^{m}.20$ (7.87 inches) of mercury. It shall be maintained during about a quarter of an hour; then the hot creosote shall be introduced by atmospheric pressure at first and then by means of forcing pumps until the cylinder is perfectly full.

These pumps shall continue to work so as to maintain in the interior of the cylinder a pressure which may reach 8 kilograms (17.6 pounds) per square centimeter (0.155 square inch) if that be considered necessary to insure as even as possible a distribution of the creosote absorbed.

The length of each of the preceding operations shall be varied to produce this result, if the usefulness of it should be recognized.

The diameter of the creosote supply pipe in the cylinder and the dimensions of the forcing pumps shall be determined so as to insure the filling of the cylinder in less than fifteen minutes.

ARTICLE 12.—*Reservations relating to the impregnation.*

The processes followed in these operations shall be subject to the approbation of the engineers of the Company, who may, if they think it best for the success of the impregnation, vary the degree and the duration of the vacuum, the temperature of the creosote, and the pressure in the cylinder, as well as the duration of each of the parts of the process.

The temperature in the interior of the cylinder, measured by means of thermometers suitably placed, must never go below thirty degrees (30°) centigrade (=86° F.) during the whole length of the process.

ARTICLE 13.—*Quantity of creosote to be applied to each tie.*

1. The creosoting of the oak ties with sapwood shall be conducted in such a manner that the sapwood shall be entirely impregnated with creosote.

2. Ties of beech: The impregnating of the beech ties shall be conducted in such a manner that the average absorption per tie shall be fifteen (15) kilograms (33.07 pounds) of creosote.

If the engineers of the company see fit to increase or diminish this quantity of creosote, the contractors shall be obliged to conform to the instructions they receive on this subject.

In that case the difference, either greater or less, between the amount of creosote really used and the amount fixed upon above shall be taken into account on the value of the ties at the price fixed by the contract.

The absorption shall be ascertained by means of a gauge, which shall indicate in the reservoir a diminishing of the liquid supposedly brought to an ambient temperature corresponding to as many times fifteen (15) kilograms (33.07 pounds) as there are ties in the cylinder.

When the ties are taken from the cylinder the absorption of the creosote shall be ascertained by boring with a gouge. All ties in which the creosote has not penetrated to a depth of three centimeters ($0^{m}.03$=1.18 inches) shall be refused and subjected to another injection.

By virtue of experiment the absorption of the creosote may be ascertained, besides, by weighing, before and after impregnating, the ties which are put in the cylinder. For this purpose the contractors must place scales in the lumber yard.

The agents of the company may take any other means which they think necessary to ascertain the amount of creosote absorbed by the ties.

ARTICLE 14.—*Supervisor of the impregnating of the ties.*

The company shall have one or more agents supervise all the processes relating to the impregnating of the wood, in order to ascertain that the work is carried on under favorable conditions.

ARTICLE 15.—*Room reserved for the agents charged with the supervision of the creosoting.*

A room with a separate entrance shall be reserved on the premises of the lumber yard, to be put at the disposal of the company's agents. It shall be warmed, lighted, and kept in order by the care of the contractors.

ARTICLE 16.—*Renting of the company land occupied by the lumber yard.*

The grounds where the creosoting yard is set up shall be rented of the company by the contractors, in virtue of a special lease whose duration shall be equal to that of the contract.

ARTICLE 17.

Patent right.—The amount to be paid to the inventors for patent rights shall be entirely at the cost of the contractors, who will insure the company against any claim of that sort.

D. T.

MANAGEMENT OF WORKS. WESTERN RAILROADS OF FRANCE. GENERAL SERVICE.

CIRCULAR.

Object: Instructions concerning the depth to be given to the ballasting of tracks.

PARIS, *July 5th, 1893.*

The depth to be given to the ballasting, which was usually fixed at $0^{m}.60$ (23.6 inches) on the lines established previous to the last few years, has been reduced by various ministerial decisions to $0^{m}.50$ (19.7 inches) for the lines now in construction.

The depth of $0^{m}.60$ (23.6 inches) presumed the upper surface of the ballasting to be level with the top of the rail in order that the spikes which hold the rails in the chairs might be well covered with ballasting. According to this supposition, the depth of $0^{m}.60$ (23.6 inches) is distributed in the following manner:

	Meter.	Inches.
Depth corresponding to the height of the rail	0.13	5.1
Depth corresponding to the base of the chair	.05	2.0
Depth corresponding to the thickness of the tie	.14	5.5
Total	.32	12.6
Remainder for the depth of the ballasting under the tie	.28	11.0
Total depth of the ballasting	.60	23.6

In reducing the total depth of the ballasting to $0^{m}.50$ (19.7 inches), it is necessary to determine in what manner this depth is to be distributed.

The steel spikes, the use of which is becoming more general, do not need to be covered by the ballasting, and therefore it is not necessary that the ballasting should be level with the top of the rail. On the other hand, the depth of the ballasting under the tie forming the true roadbed can not be perceptibly reduced. Starting, then, with the ballasting under the tie of a depth of $0^{m}.25$ (9.84 inches), considered indispensable, the total depth of $0^{m}.50$ (19.7 inches) will be distributed thus:

	Meter.	Inches.
Depth of the ballasting under the tie	0.25	9.8
Depth of the ballasting corresponding to the thickness of the tie	.14	5.5
Depth of the ballasting corresponding to the base of the chair	.05	2.0
Total	.44	17.3
There will remain, therefore, for the depth of the ballasting, corresponding to the height of the rail	.06	2.4
Total depth of the ballasting	.50	19.7

The total height of the rail being $0^{m}.130$ (5.1 inches) for the rail D. C. of 38 K. 75 and $0^{m}.142$ (5.6 inches) for the rail D. C. of 44 K., the ballasting must be leveled off below the surface of the rail—$0^{m}.07$ (2.76 inches) for the rail of 38 K. 75 and $0^{m}.082$ (3.23 inches) for the rail of 4 K.

For the roads already established with a depth of ballasting of $0^{m}.60$ (23.6 inches), and having wooden spikes, this depth may, as stated above, be reduced to $0^{m}.50$ (19.7 inches) by degrees as the ballasting is renewed and steel spikes substituted.

Under no circumstances should the depth of the ballasting under the tie be reduced to less than $0^{m}.20$ (7.87 inches).

In curves, where, on account of the increased height of the outer rail, the position of the tie on the ballasting is inclined, the depth of the ballasting in the axis of the track must be regulated in such a manner as to have the minimum depth at least $0^{m}.20$ (7.87 inches) under the end of the tie on the inside of the curve.

As to the width of the driftway of the ballasting, it is fixed at $1^{m}.00$ (39.37 inches) by article 7 of the specifications of June 11th, 1859. However, it is absolutely impossible to obtain this width on lines where the roadbed has been made with a reduced width, such as on a few tracks constructed when railroads were first built, on certain lines of local concerns which have been brought in, or on others actually in construction, for which a width of 5 meters (16.4 feet) has been adopted as the width of the roadbed for a single track. Under no circumstances should the width of these driftways be reduced to less than $0^{m}.80$ (31.5 inches). To obtain this width the slope of the ballasting may, if necessary, be made as steep as its nature will permit, or, if this can not be done, the footway at the base of the ballasting may be diminished. This footway when normal should have a width of $0^{m}.50$ (19.7 inches), and should always be clearly defined even when reduced in width.

Only for roads with a narrow track shall the width of the driftway of the ballasting be reduced to $0^{m}.75$ (29.5 inches), conformably with article 2 of the convention of March 25th, 1885.

Director of Works.
E. Clerk.

Exhibit G.[a]

London, Brighton and South Coast Railway Company.

SPECIFICATIONS AND CONDITIONS OF CONTRACT FOR CREOSOTED REDWOOD SLEEPERS.

1. This proposed contract is for the supply and delivery of—
——— sleepers at Deptford Wharf,
——— sleepers at New Haven Wharf,
or any less number that the directors may decide to accept.

2. The dimensions are to be the customary 9-ft. length (say 8$\frac{11}{12}$ ft.) 10 by 5 ins. rectangular, cut from square blocks out of which neither more nor less than two sleepers can be sawn (no centers will be accepted).

3. The quality shall be the best Baltic redwood fir, in good condition, free from shakes, dead knots, and other defects.

4. Sixty per cent of the sleepers to have on one side a flat surface not less than 9 ins. wide throughout the length, and the remainder to have on that side a flat surface not less than 8 ins. wide throughout the length. All sleepers to have a flat surface not less than 10 ins. wide on the other side, with sharp edges throughout the length.

5. Ninety per cent of the sleepers to have not less than 8½ ins. and the remainder not less than 7 ins. diameter of heart at both ends.

6. The blocks from which the sleepers are cut must be of last autumn's deflotation at the port of shipment; any delivered of an earlier deflotation will be rejected.

7. The sleepers are to be cut and stacked from four to six months (or until they are considered sufficiently dry by the company's engineer or his inspector) before they are creosoted. They are to be adzed to a true plane for a width of 17 ins. at each end for the chair seating, and 40 per cent, or such other percentage as may be required, are to be bored with eight holes, namely: Two 1⅛ ins. diameter at each end (for trenails) and two ⅝ in. diameter at each end (for spikes). A template showing the position of these holes will be provided by the company, and the contractors must bore the holes exact to it and perfectly true through the sleepers.

8. The sleepers will be inspected at the contractor's wharf before being creosoted, and the engineer shall have power, personally or by deputy, to reject any sleepers he may consider inferior, either in quality of timber or from any deviation from the specification, and his decision in the manner shall be final.

9. The sleepers when sufficiently dry are to be placed in a wrought-iron cylinder, and when closed a vacuum is to be created by air pumps. The creosote, at a temperature of 120° Fahr., is to be allowed to enter the exhausted cylinder, and afterward maintained there by pumping at a pressure of not less than 120 lbs. to the square inch. The sleepers are to be kept under this pressure until each sleeper has absorbed at least 3 galls. of creosote on the average, the quantity to be ascertained by weighing,[b] any charge of sleepers not giving the average impregnation of at least 3 galls. to be returned to the cylinder for further treatment.

10. The creosote to be a pure coal-tar distillate of the very best quality, free from water and all impurities, and on analysis to give the following results:

To be entirely liquid at a temperature of 120° Fahr. and remain so on cooling to 93 degrees.

To contain not less than 25 per cent of constituents that do not distil over at a temperature of 600° Fahrenheit.

To yield, to a solution of caustic soda, not less than 6 per cent by volume of tar acids.

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[a] Reprinted from Chanute. Preservation of Railway Ties in Europe.

[b] In practice one trolley is weighed out of each charge.

The specific gravity at 90° Fahr. to range between 1.040 and 1.065, water being taken as 1.000 at the same temperature.

11. The contractor is to supply a copy of the analysis of each delivery of the creosote oil used, in the terms of the specification, and the engineer shall be at liberty to take samples of the oil from time to time and have the same tested, the contractor paying the cost of the analysis to the extent of one analysis for each 10,000 sleepers. Any additional analysis to be made at the company's expense.

12. Delivery shall be made alongside the company's New Haven and Deptford wharves, at either of the rates mentioned below, at the option of the company's storekeeper, until the contract is completed. Delivery at Deptford will be taken by open barges containing not more than 1,800 sleepers each. The craft to take regular turns for discharging and conform to the regulations of the company's wharves: At Deptford, to commence ——— and continue at the rate of ——— sleepers per week. At New Haven, to commence ——— and continue at the rate of ——— sleepers per week.

13. Should the contractor fail to deliver the sleepers, or any portion of them, as stipulated in condition No. 12, the directors may cancel the contract, or the residue thereof, and obtain other supplies in such manner as they think fit, and the contractor shall pay to the company any extra cost and expenses incurred by such failure, or the directors may deduct the amount from any sum then due or becoming due to the contractor.

14. The shipping port or ports must be named in the tender; and if more than one port, the number of sleepers proposed to be shipped at each port must also be given; bills of lading to be produced by the contractor when required.

15. The price per sleeper is to include every charge except wharfage and landing at the company's wharves.

16. For sleepers delivered and approved during one month payment will be made at the company's next monthly pay day by cash, less 2½ per cent discount, provided the company have no claim on the contractor as specified in condition No. 13. In case of any dispute arising between the contractor and the company or their agents as to the meaning of any of the terms and conditions of this contract, the decision of the company's engineer shall be final and binding upon all parties.

17. The contractor shall, if required, enter into and sign a formal contract with the directors and find good and sufficient surety to guarantee its proper fulfilment; the expense of such contract and bond to be paid by the company.

18. The directors do not bind themselves to accept the lowest or any tender.

19. The tenders are to be returned by post, addressed to "The Secretary, L., B. & S. C. R., London Bridge, S. E.," and must reach him not later than first post on ———, endorsed on the outside cover "Tender for sleepers."

——— ———,
Storekeeper.

General Stores Office,
New Cross, S. E.

Exhibit H.

Northern Railway Company, France.

Specifications—1893.

For furnishing beech ties of usual shape, creosoted by the new "Blythe" process, called thermo-carbolization.

Article 1. The present specifications refer to the furnishing of ordinary ties for the extension and maintenance of tracks upon the company's various lines.

Article 2. The ties shall be of beech, creosoted by the new "Blythe" process (called thermo-carbolization).

ARTICLE 3. The ties shall be rectangular, or present one of the sections shown in figs. 26 and 27.

The top and bottom faces shall be sawed; the sides may be hewed.

The bottom face, which rests on the ballast, shall be square edged; the two lateral sides shall be without wane for a minimum height of 2 ins. The top face shall be at least 4.4 ins. wide in the middle and for the whole length of the tie.

The minimum dimensions of the ties shall be as follows:

Length (2.60 m.)	8.53 ft.
Width (0.26 m.)	10.2 ins.
Thickness (0.13 m.)	5.1 ins.

ARTICLE 4. The ties shall be practically straight. If curved sideways, the incurvation shall not be more than $\frac{1}{20}$ of the whole length. All ties will be rejected whose bottom face is longitudinally curved, being either convex or concave.

The ties shall be sawed off square at the ends.

ARTICLE 5. The beech wood must be perfectly sound and of the best quality. It shall be neither heart-shaken, nor frost-split, nor brashy, nor worm-eaten. It shall be exempt from dotiness, rotten knots, cracks, splits, bad knots, red-heart, or any other defect. The trees shall be felled between the 1st of November and the end of March. They shall be worked up into ties continuously, which work shall be completed by the end of April. Timber will be refused which has been felled before the 1st of November or not worked up before May 1st.

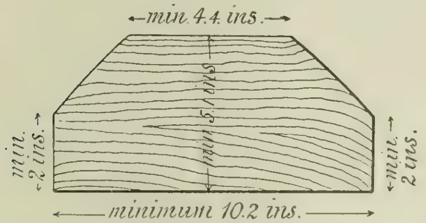

FIG. 26.—Cross-section of tie, Northern Railway of France.

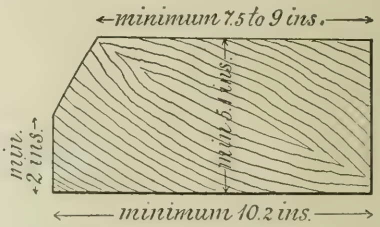

FIG. 27.—Cross-section of tie, Western Railway of France.

All the ties shall be completely barked. As fast as the ties are made they must be piled up carefully, cob-fashion. The chief engineer of the company reserves the right of putting on inspectors to follow up the felling and manufacture of the ties at various points.

ARTICLE 6.—The untreated ties will all be most carefully inspected, both as to quality and dimensions. Those accepted will be stamped at the ends with the company's marking hammer.

All the sticks with any dimensions less than the limits stated in article 3 will be rejected. Those with greater dimensions than required may be accepted, but no allowance will be made for oversize, the ties being purchased by the piece and not by the cubic meter.

If a tie of good quality and otherwise acceptable shows a crack likely to spread open the contractor shall bolt the two parts together or insert an S in the end at his own expense. Every tie split open at the end for its whole width or thickness shall be rejected.

The rejected ties will be left on the hands of the contractor at the point of inspection; they will be so marked as to preclude them from being again offered for inspection.

ARTICLE 7.—The untreated ties must be well seasoned before preparation, and, so far as possible, adzed and bored by the company to fit the rails and the lag screws. The seasoning will be tested by weighing a number of ties haphazard. The weight of the timber thus ascertained must not be more than 46.7 lbs. per cubic foot.

Article 8.—The ties will be injected with creosote by the new "Blythe" process, called "thermo-carbolization." In this process the ties are subjected to the two following operations:

1. They are enclosed in a cylinder of boiler plate and subjected to a current of steam mixed with creosote oil vapor for a length of time sufficient to insure, during the second operation, the absorption of the prescribed quantity of creosote.

2. The cylinder containing the ties is then filled with a sufficient quantity of crude creosote. This liquid, maintained at a temperature of at least 140° Fahr., is compressed in the cylinder by steam to five atmospheres from the generator, during a sufficient length of time so that the total quantity of creosote injected into the wood, both as a vapor and as a liquid, shall be at least 24.4 lbs.[a] per tie.

If the engineer of the company deems it advisable to increase this quantity of creosote, the contractor will comply with the indications which he may receive relating thereto.

Article 9.—The creosote shall consist of the mixture of volatile products heavier than water distilled from coal tar produced by gas works. It shall contain at least 6 per cent of carbolic acid, or of analogous products soluble in caustic soda. It shall be entirely soluble in benzine, and completely liquid at a temperature of 122° Fahrenheit. It must, moreover, conform to the samples which the contractor shall submit to the company's engineer.

The contractor shall specify from what gas works each shipment of creosote is received.

Article 10.—The company shall take cognizance of all the operations relative to the inspection of the wood, through an inspector appointed by the chief engineer. Such inspector shall satisfy himself as to the thorough application of the "Blythe" process, shall keep accounts of the wood injected, and shall verify the results of the injection. He will report, upon a special blank, the following points for each operation:

1. The length of time of application of the mixed steam and oils coming from the vaporizer, as well as the final pressure in this operation, which must be at least five atmospheres.

2. The time occupied in filling the cylinder with crude creosote, the final pressure, and the quantity of liquid absorbed during this operation.

3. The quantity of crude creosote introduced in the vaporizer and in the lower reservoir. This quantity shall not be less, for ten consecutive operations, than an average of 24.2 lbs. per tie injected.

4. Finally, the inspector shall keep an exact account of the total quantity of creosote which the contractor shall receive at the works for injection, so as to check the amount of liquid absorbed during each season's work.

The chief engineer of the company reserves, moreover, the right of using any other checks which he may deem desirable to control the quantity of creosote injection into the wood, either as a mixture of vapors or in the liquid state.

The royalties to be paid to Mr. Blythe or others for the use of the patents, etc., will be at the sole charge of the contractor, who guarantees the company against any claim of this nature.

All experiments made by the company to ascertain whether the creosote is of good quality, and if the injection of the wood is complete, shall be at the charge of the contractor.

Article 11.—Upon being withdrawn from the cylinder the ties shall be inspected one by one in order to ascertain whether the injection is homogeneous and whether the quantity of 24.2 lbs. has been duly absorbed by each. This last verification shall be effected as described in section 3 of article 10.

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[a] Since increased to 35.2 lbs. per tie.

Such ties as may be incompletely injected, a fact which shall be established by cutting into them with a gouging adze, shall be subjected to a second operation, or even to a third, after which they may be declared, in case of need, as unfit for injection, and finally rejected, as well as those ties which may be deformed by the action of heat in the cylinder.

The contractor shall make no extra charge for these repeatings of treatment, and shall, moreover, either insert a bolt or an S into any tie which shall split during the treatment.

The ties accepted shall be counted and either immediately loaded on cars or piled up at some point designated by the company's agent. The ties rejected shall receive a special mark at the rail seat and will be piled at special points to be indicated to the contractor. These ties shall only be taken away upon authority given by the engineer of the company, who may hold them until the season's contract is filled, so as to avoid their being again presented for inspection by agents.

ARTICLE 12.[a] The final acceptance of the ties shall only take place six months after the full delivery of the season's contract.

Until this final acceptance the company reserves the right of rejecting any ties which may possess defects not detected upon a first inspection, or which may split by reason of a bad quality of wood.

The ties so rejected will be surrendered to the contractor at the point of delivery, who shall either deduct them from his bill or furnish other ties if required by the company.

ARTICLE 13. The contractor shall be governed, save in such modifications as result from the present specifications, by the clauses and general conditions imposed upon contractors doing work for the Northern Railway Company, through the rules drawn up September 26th, 1892, by the chief engineer of the Ponts et Chaussées, Chief engineer of Maintenance of Way, approved October 21st, 1892, by the Executive Committee of said Company, and registered in Paris the 28th of the same month.

EXHIBIT I.

IMPERIAL RAILWAYS OF ALSACE-LORRAINE, GERMANY.

Specifications for impregnating wooden railroad ties—1898.

SECTION 1. For pine ties the impregnating fluid is a solution of chloride of zinc, with an addition of coal-tar oil containing carbolic acid; for beech or oak ties hot coal-tar oil containing carbolic acid must be used.

SECTION 2. The process of impregnating by chloride of zinc solution, with addition of coal-tar oil containing carbolic acid, is divided into three parts:

1. Steaming of the ties.
2. Production of a partial vacuum and admission of the impregnating fluid.
3. Compression (forcing in) of the impregnating fluid.

The ties are loaded on iron cars, which are pushed into the impregnating cylinder; this is closed air-tight, and they are exposed to the action of steam; steaming is continued for a longer or shorter period, according to the time of year and the condition of the ties. The admission of steam into the impregnating cylinder must be regulated in such manner that an inside pressure of 1.5 atmospheres

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[a] The same contractor furnishes the ties and treats them.

(22 lbs. per square inch) above air pressure is reached within 30 minutes. For dry ties it will suffice to maintain this pressure in the impregnating cylinder for 30 minutes longer, but for green ties it should be kept up for another hour. For dry ties, therefore, the steaming takes at least 1 hour, while for green ties at least 1½ hours are necessary. A gauge attached to the cylinder indicates existence of the specified pressure. The valve at the bottom of the cylinder must be opened on admitting the steam, in order that the air contained in it may be driven out, but should be closed when steam begins to blow out. This valve should be opened repeatedly, as fast as steam condenses; open it at least every half-hour to draw off the water, and for the last time just before exhausting the air. When steaming is finished, the steam remaining in the impregnating cylinder is allowed to escape.

After steam is discharged a partial vacuum is produced in the cylinder containing the ties, until the vacuum gauge shows at the least a column of mercury of 60 cm. (23.6 ins.); this partial vacuum must be maintained for ten minutes. On expiration of this time, while continually preserving the partial vacuum, allow the impregnating fluid, which meanwhile has been prepared in a separate vessel and heated to at least 65° Cent. (149° Fahr.), to enter the impregnating cylinder, filling it entirely. To prepare the impregnating fluid, add, while heating, 1 kgr. (2.2 lbs.) of coal-tar oil to every 15 kgr. (33 lbs.) (6⅔ per cent) of the solution of zinc chloride.

To insure as perfect a mixture of the solution of zinc chloride with the coal-tar oil as possible, an effective stirring apparatus, combined with injection of steam and air, must be applied.

Next a pressure pump is used to exert an excess of seven atmospheres above air pressure, this pressure to be maintained for not less than 30 minutes. If necessary, continue it for a longer time until the ties have absorbed a certain amount of impregnating fluid, as specified hereafter. The impregnating fluid is then run off.

The chloride of zinc solution intended for impregnating must be as nearly as possible free from foreign substances, and there must be no free acid. An admixture of other metals, notably iron, can only be allowed in a very slight percentage and only if it can not be avoided in the manufacture. The solution must have a strength of 3.5° Baumé = 1.0244 specific gravity at a temperature of 15° Cent. (59° Fahr.).[a] The solution contains 1.26 per cent of metallic zinc.

The coal-tar oil used must not contain over 1 per cent of oils that boil below 125° Cent. (257° Fahr.). It must be so little volatile that its boiling point lies mainly between 150° and 400° Cent. (302° and 752° Fahr.). In no case is it permissible to have more than 25 per cent of its weight volatilized below 235° Cent. (455° Fahr.). It must contain at least 20 to 25 per cent of acid substances (creosote or oils resembling carbolic acid) that are soluble in caustic lye of soda of 1.15 specific gravity. The coal-tar oil must be entirely liquid at +15° Cent. (59° Fahr.), and as much as possible free from naphthalene, so that on evaporation (fractional distillation) produced in a glass vessel in groups of 50 each it shall leave a residue of not more than 5 per cent of naphthalene. Its specific gravity should not be less than 1.020 at a temperature of +15° Cent. (59° Fahr.) and should not exceed 1.055. To remove such impurities from the impregnating fluid as are due to the process, suitable settling (clarifying) apparatus should be provided.

The contractor is required to report where he obtains his supplies of zinc-chloride solution and of coal-tar oil, intended for use, and to furnish samples of the same to the supply office of the Imperial railways at Strassburg, in Alsace, before commencing to impregnate. He will be permitted to purchase the solution of zinc chloride and the carbolized oil of coal tar only from such factories whose samples have been approved by the management of the railways. The railway management reserves the right to test the fluids used at any time.

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[a] 3.5° B. corresponds to 2.62 per cent dry zinc chloride. Hence, 19 × 2.62 per cent amounts to 0.498 lb. of dry zinc chloride per cubic foot.

It is specified that the average absorption of impregnating fluid contained in every charge of the cylinder shall be the following:

(A) Absorption of 35 kgr. (77 lbs.) for each tie of the first class, length of 2.70 m. (8.85 ft.).

(B) Absorption of 26 kgr. (57 lbs.) for each tie of the second class, length of 2.50 m. (8.2 ft.).

(C) Absorption of 310 kgr. per cubic meter (19 lbs. per cubic foot[a]) for ties of other dimensions.

To determine the amount of impregnating fluid absorbed by the ties, the following method must be adopted:

Weigh all ties on a platform scale placed under roof immediately before steaming them and again after impregnating when dripping has ceased. The difference in weights equals amount of impregnating fluid absorbed. A deduction of 15 pfennigs per 10 kgr. (16 cents per 100 lbs.) will be made for shortage shown by this weighing test. In case the shortage amounts to more than one-sixth of the absorption specified the impregnation must be repeated. If, on the other hand, the weighing shows that the ties have absorbed more than the amount specified, a bonus of 15 pfennigs for every 10 kgr. (16 cents per 100 lbs.) will be paid for such increase up to a maximum of 15 per cent.

SECTION 3. The work of impregnating with hot carbolized oil of coal tar (i. e., oil of coal tar containing carbolic acid) must be divided into two parts:

(1) Drying of the ties, i. e., withdrawing water from them.

(2) Introduction of oil of coal tar under pressure.

The ties are run into the impregnating cylinder and this is closed air-tight. Next, a partial vacuum, equal to at least 60 cm. (23.6 ins.) column of mercury, is produced in the impregnating cylinder and maintained for 10 minutes, and thereupon, while keeping up the vacuum, the hot oil of coal tar is made to flow in until it rises to a level that will prevent sucking over by the air pumps. The flowing in of the coal-tar oil may be accomplished all at once or at intervals, according to the dryness of the ties. While thus filling up, and afterwards, the coal tar is heated up inside the cylinder to at least 105° Cent. (221° Fahr.), but not higher than 115° Cent. (239° Fahr.), by means of steam coils. This heating should be accomplished during a space of time not less than 3 hours. When this temperature is reached in the impregnating cylinder, it must be kept up for another hour, either with or without the partial vacuum, as may be judged necessary, in order that the ties may absorb the specified amount of oil of coal tar.

The impregnating cylinder is connected with a pipe condenser from the instant that filling with hot coal-tar oil commences, and all the aqueous vapors driven out of the ties are condensed in this, the water being carried to a tank. This receiver must have a water gauge from which one can read off the amount of water evaporated from the ties.

After the drying of the ties or the extraction of water from them is finished the impregnating cylinder is filled completely and the pressure pump started, which must produce a pressure of at least 7 atmospheres. This pressure is to be maintained for at least 30 minutes in treating beech ties and 60 minutes for oak ties, unless it proves necessary to prolong the time to obtain the amount of absorption specified. The oil of coal tar is then drawn off.

---

[a] 3.5° B. corresponds to 2.62 per cent dry zinc chloride. Hence, 19 × 2.62 per cent amounts to 0.498 lb. of dry zinc chloride per cubic foot.

The coal-tar oil used must be heavy oil, derived from the distillation of coal tar, of greenish-black color, specific gravity of 1.045 to 1.100 at 15° Cent. (59° Fahr.), boiling point between 150° and 400° Cent. (302° and 752° Fahr.).

While making fractional distillation no oils must pass over below 150° Cent. (302° Fahr.) and not more than 25 per cent of the volume at temperature up to 235° Cent. (455° Fahr.).

The coal-tar oil must contain by volume at least 10 per cent of carbolic acid and, at a temperature of 15° Cent. (59° Fahr.), must be free from naphthalene and show no sediment.

To determine percentage of carbolic acid, apply agitation to the oils heated to 400° Cent. (752° Fahr.) with a caustic solution of soda having specific gravity of 1.15. The difference in volume of oil before and after agitation gives percentage of carbolic acid.

The contractor is required to state source of supply for his coal-tar oil and to furnish samples to the supply office of the Imperial railways at Strassburg before he commences work of impregnation. The coal-tar oil can only be purchased from factories whose samples have been approved by the railway management. The railway management reserves the privilege of at any time testing the coal-tar oil used.

It is specified that the average absorption of coal-tar oil for every charge of the cylinder shall be:

(*a*) For one railroad tie, 1st class, 2.70 m. (8.85 ft.) long, of oak wood, 11 kgr. (24 lbs.); of beech wood, 36 kgr. (79 lbs.).

(*b*) For one railroad tie, 2d class, 2.50 m. (8.20 ft.) long, of oak wood, 8 kgr. (18.6 lbs.); of beech wood, 28 kgr. (61.6 lbs.).

(*c*) For ties of other dimensions per cubic meter (35.3 cu. ft.), of oak wood, 100 kgr. (220 lbs.); of beech wood, 325 kgr. (715 lbs.).

To determine the amount of coal-tar oil absorbed by the ties, these are weighed before the impregnation and again after it, when dripping of oil has ceased, using a platform scale placed under a roof. The difference in weight is amount of coal-tar oil absorbed. Correct the weight of the ties before impregnation by deducting from it weight of water delivered by condenser to the tank and obtained from the vapors distilled while drying in hot coal-tar oil, as weight of ties is reduced to this extent by drying process. If on examination it is proved that absorption amounts to less than five-sixths of that specified, the impregnation must be repeated.

For every shortage in coal-tar oil shown by above test a deduction of 50 pfennigs for 10 kgrs. (54.5 cents per 100 lbs.) will be made, but, on the other hand, an increase in absorption will be paid for at the same rate, a maximum of 15 per cent increase being the limit of such payment.

SECTION 4. The contractor is required to give eight days' notice to the supply office of the time of intended commencing to impregnate ties, in order that the office may send an official to supervise same. This official must be freely admitted at all times to the plant of the contractor, and all desired information must be readily furnished him. The contractor must furnish all necessary appliances, apparatus, and labor to make tests without charge.

SECTION 5. In case the contractor does not supply his own ties, the parties furnishing them will be required to deliver f. o. b. cars at the station nearest to the impregnating works, provided they are shipped by rail. Ties delivered by wagon or other conveyance will be delivered loaded at storage yards of the factory without charge.

The hauling of ties from the station to factory will be at the expense of the contractor for impregnation. He has also to provide for unloading, piling, and handling of ties as per regulations. The contractor will be paid for this labor the amount of 8 pfennigs (1.92 cents) for each track tie and 4 pfennigs (0.96 cent) for each switch tie of 1 m. These prices cover the expense of labor and tools required in receiving green ties as well as that of reloading rejected ties, payment for a tie to be made only once.

SECTION 6. The contractor for impregnating is held liable for all damages and loss of ties that may occur from the time they are delivered to him at the railroad station, or at his works, as long as ties remain at his works. This liability includes losses by fire occurring at the impregnation works and by theft committed while ties remain there. The contractor must pay the value of all missing ties or of such as become unserviceable previous to their return after impregnation, but is not liable for splitting. He is, however, required to furnish without charge all necessary S hooks and bolts for drawing together the cracks occurring during storage, and has to drive or put these in according to directions of the supervising official.

When ties are turned over to the contractor for impregnation, they are already supplied with S hooks needed to draw together all existing cracks. Each beech track tie is also fitted with two iron bolts running through it about 10 cm. (4 ins.) from each end in the direction of its breadth. It is his duty, therefore, to supply without charge only such S hooks and bolts as may be needed thereafter, and of the same kind, and to fasten them.

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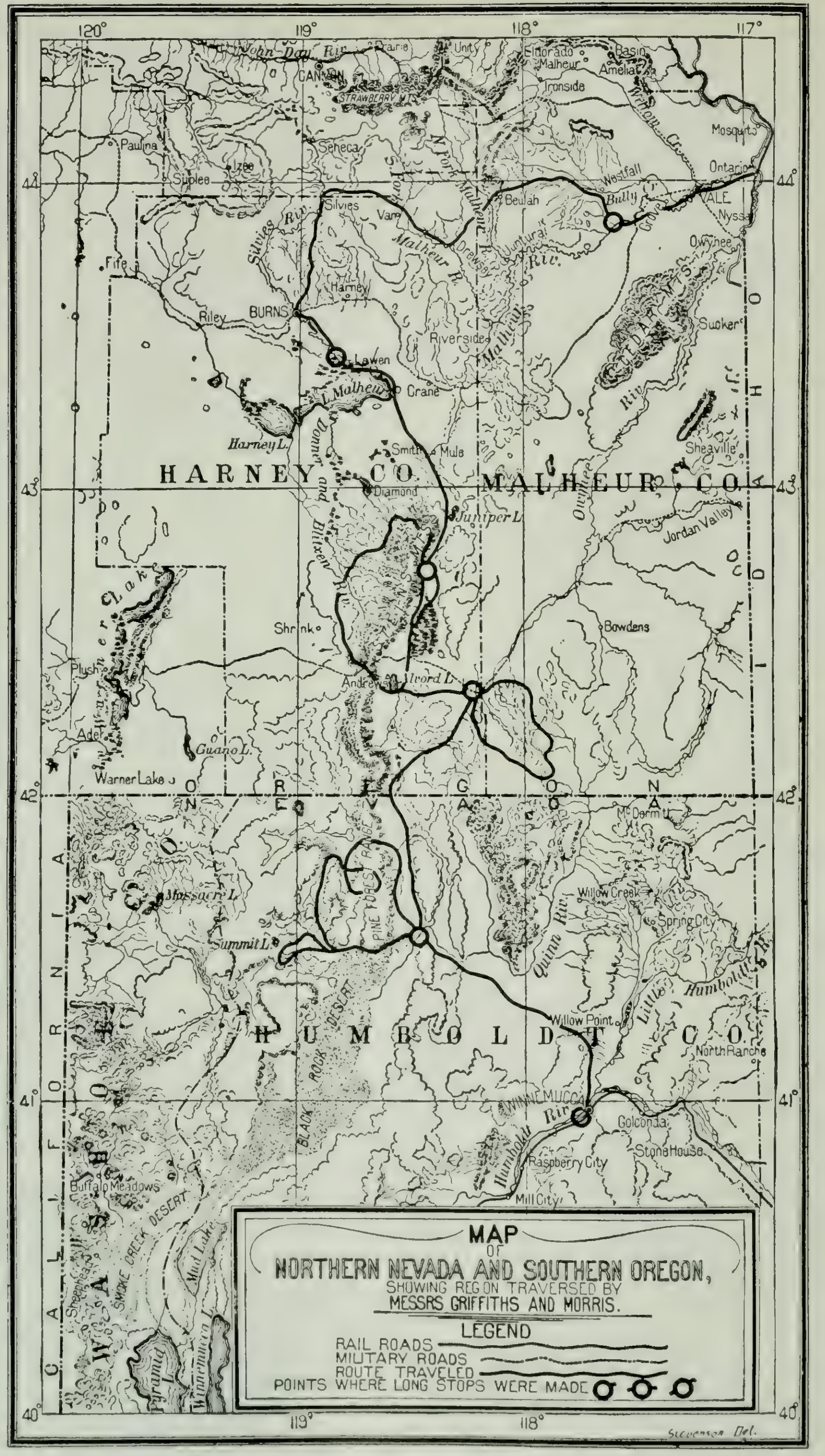

MAP
OF
NORTHERN NEVADA AND SOUTHERN OREGON,
SHOWING REGION TRAVERSED BY
MESSRS GRIFFITHS AND MORRIS.

LEGEND
RAIL ROADS
MILITARY ROADS
ROUTE TRAVELED
POINTS WHERE LONG STOPS WERE MADE

120°
119°
118°
117°
44°
43°
42°
41°
40°
John Day Riv.
Prairie
Unity
Eldorado
Malheur
Basin
Amelia
CANYON
STRAWBERRY MTS.
Ironside
Mosquito
Paulina
Seneca
Izee
Suplee
Westfall
Ontario
Silvies
Vale
VALE
Beulah
Bully Cr.
Nyssa
Silvies Riv.
N. Fork Malheur R.
Malheur R.
Drewsey
Juntura
Riv.
Owyhee
Fife
Harney
Riley
BURNS
Riverside
Lawen
Sucker
L. Malheur
Crane
Harney L.
Smith
Mule
Sheaville
HARNEY CO.
MALHEUR CO.
Diamond
Juniper L.
Jordan Valley
Owyhee Riv.
Warner Lake
Shrink
Bowdens
Plush
Andrews
Alvord L.
Adel
Guano L.
Warner Lake
OREGON
NEVADA
IDAHO
McDermitt
Massacre L.
Willow Creek
Spring City
Summit L.
PINE FOREST RANGE
Quinn Riv.
BLACK ROCK DESERT
Willow Point
Little Humboldt R.
HUMBOLDT CO.
North Ranche
WINNEMUCCA
Humboldt Riv.
Golconda
Stone House
Raspberry City
Mill City
Buffalo Meadows
SMOKE CREEK DESERT
Mud Lake
Pyramid L.
Winnemucca L.
WASHOE CO.
CALIFORNIA
Stevenson Del.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN No. 15.

B. T. GALLOWAY, Chief of Bureau.

FORAGE CONDITIONS ON THE NORTHERN BORDER OF THE GREAT BASIN,

BEING A

REPORT UPON INVESTIGATIONS MADE DURING JULY AND AUGUST, 1901,
IN THE REGION BETWEEN WINNEMUCCA, NEVADA,
AND ONTARIO, OREGON.

BY

DAVID GRIFFITHS, Expert in Charge of Field Management,
GRASS AND FORAGE PLANT INVESTIGATIONS.

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1902.

LETTER OF TRANSMITTAL

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., December 1, 1901.

Sir: I have the honor to transmit herewith a paper on Forage Conditions on the Northern Border of the Great Basin, and respectfully recommend that it be published as Bulletin No. 15 of the Bureau series. The paper was prepared by Mr. David Griffiths, expert in charge of field management, Grass and Forage Plant Investigations, and was submitted by the Agrostologist.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

In July, 1901, Dr. David Griffiths, expert in charge of field management, accompanied by Mr. E. L. Morris, was commissioned to visit northern Nevada and southern Oregon to investigate the range conditions in that section, and the results of his observations are embodied in this bulletin.

Comparatively little was previously known as to the existing conditions in this region, and the present report shows the pressing need of reform in range management—a matter which applies not only to this section, but to all the open ranges in the West. Throughout the entire West, as the better land has been taken up by settlers the cattle and sheep ranges have become more restricted, and stock are now forced back from the fertile river bottoms and other lands so situated as to make irrigation possible, and the inevitable result has been overstocking of these restricted and poorer ranges, with all the attendant evils.

In pursuing his investigations Dr. Griffiths visited the Pine Forest, Bartlett Peak, Steins, White Horse, Blue, and Bendire mountains, the valleys of the Humboldt, Quinn, Silvies, and Malheur rivers, and the basins of the Alvord Desert and Malheur Lake, thereby traveling about 700 miles between July 17 and August 30. In furtherance of these investigations, Hon. J. P. Irish and Mr. John Gilcrest, superintendent of the Miller and Lux and the Pacific Live Stock companies' interests in Nevada and Oregon, furnished transportation, guides, and living expenses for the party for practically the entire trip from Winnemucca, Nev., to Ontario, Oreg.; and to both Mr. Irish and Mr. Gilcrest we are greatly indebted for courtesies shown during the trip. Acknowledgment is also here made to the Bureau of Soils of this Department for the analysis of soil samples collected on the trip.

F. Lamson-Scribner,
Agrostologist.

Grass and Forage Plant Investigations,
Washington, D. C., November 29, 1901.

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B. P. I.—18 Agros.—96

FORAGE CONDITIONS ON THE NORTHERN BORDER OF THE GREAT BASIN.

INTRODUCTION.

The area of our public grazing lands has decreased so steadily with the tide of westward emigration that the stock industry, which once flourished on the magnificent pastures of the public ranges, is now driven into situations either too arid or too rugged for the husbandman's use. From a natural tendency to increase rather than to diminish the number of stock has resulted a condition of shortage of feed, which was foretold years ago by those who were then studying the treatment of the ranges. This condition has awakened great activity in investigations of questions pertaining to the preservation of the feed supply of the public pasture lands. So numerous are the requests for information, advice, and suggestions for the improvement and management of the ranges which are received in the office of the Agrostologist that it is very difficult to give all of them the attention which they deserve.

In response to one of these requests the writer and Mr. E. L. Morris were commissioned to make a tour of a portion of the ranges of northern Nevada and southeastern Oregon for the purpose of determining the condition of the forage supply and ascertaining, if possible, some method of treatment of the range and pasture lands which would tend to increase the efficiency of the pastures and hay meadows.

A request from the secretary of the Eastern Wyoming Wool Growers' Association, that a representative of the office visit the midsummer meeting of that body for the purpose of addressing the members in attendance on range and forage plant problems, was received prior to our departure for the field. Arrangements were therefore made to attend the meeting of this association, held at Douglas, Wyo., July 10, 11, and 12 to give such information and advice as seemed best calculated to be of service to those in attendance and to acquaint them with the work of the office of the Agrostologist. The interest which naturally exists in forage and range problems was abundantly exhibited in the meetings and by the attitude of the members toward forage problems as they came before them. The programme itself exhibited this interest in no mistakable terms, for there were three places allotted to addresses on the various phases of grass and forage problems and range reclamation by as many persons. The problems of greatest interest to the meeting appeared to be those relating to the most promising arid land species of forage plants, forage plants for alkali soils, and methods of range management having for their object the greatest permanent efficiency of the native pastures.

After the conclusion of the meeting at Douglas the party proceeded directly to Winnemucca, Nev., and began its work along the Humboldt River bottoms. The lines of investigation covered every phase of forage plant and range questions in the region, and necessitated work along about six lines, namely, studying the native ranges, securing information from the ranchers in the region relative to former conditions, collecting specimens, gathering seed of promising native species of forage plants, digging soil samples, and taking photographs illustrating the various features of the work.

After a few days' work on the Humboldt River bottoms in the vicinity of Winnemucca, the party started northward, making several short stops before reaching Quinn River crossing, 75 miles to the northwest. Here we made our headquarters until the 1st of August. Being a representative and rather favorable locality, we found an abundance of very interesting and profitable work. From here we outfitted for a trip to the ranches surrounding the Pine Forest Mountains, all of which are known locally as part of the "Quinn River outfit," stopping en route at the ranches known as Big Creek, Alder Creek, and Leonard Creek. From Alder Creek a trip was taken into the Pine Forest Mountains, and from Leonard Creek into the mountains in the vicinity of Summit Lake and Bartlett Peak, both under the guidance of Mr. Robert Bowling.

On the 1st of August we crossed the Nevada-Oregon line at Denio and the next day reached the White Horse Ranch, near the site of old Fort Smith. Work was confined here to hay and pasture meadows and to a two days' trip into the White Horse Mountains, a low range forming the watershed between the Quinn River and the Alvord drainages. Our route was along the divide skirting the headwaters of Willow, Cottonwood, and White Horse creeks. The next stop was made at the Wild Horse Ranch, near Andrews. This property is but little improved and therefore affords an excellent opportunity for studying the condition of the native meadows of the region. Here we secured a pack outfit, consisting of three saddle horses and two mules, for a trip into Steins Mountains, under the guidance of Mr. Joe Bankofier. A special effort was made to traverse the region known as the summer range, where the greatest number of stock is usually found at this time of the year. The mountains were ascended from the Wild Horse side by the trail leading to Ankle Camp, a round-up station in the mountains. From here on until within a few miles of Manns Lake there was practically no trail, except such as had been made here and there by cattle and sheep traveling to and from water and feed. In no case did we reach the highest elevation on the mountains, but skirted them on the west and north along the broad broken table-lands where so much pasturing is done. Our course led across and somewhat below the sources of the Blitzen, Mud, Indian, and Cocoamongo creeks. From Manns Lake we returned to Wild Horse along the traveled road between the Alvord Desert and the base of the mountains, having in this manner surrounded the main divide of Steins Mountains and having traversed the main summer range of the region, accomplishing in this mountain range a similar survey of the country as we did in the Pine Forest and adjacent ranges in northern Nevada. Returning from Wild Horse to Manns Lake, a couple of days were spent in the vicinity of Divine's ranch, which extends from the eastern slope of Steins Mountains to the Alvord Desert. The next stop of any length of time was made on the Island Ranch, between the forks of Silvies River, 15 miles south of Burns. From here we traveled by rather rapid stages to Ontario, passing en route Silvies, Calamity Settlement, Drewsey, Beulah, Westfall, and Vail. Short stops of one to three days were made near Silvies and Beulah, and at Indian Creek and Harper ranches.

For some features of the work conditions were not at all favorable. The region should have been visited about twenty days earlier for the collection of specimens. Many important things on the desert were so far gone when we arrived that good specimens could not be obtained; but, while there was loss in this respect, we were able to secure a large quantity of seed, especially of the valuable wild wheat (*Elymus triticoides*); and we were in just the right time for the study of the native hay meadows and the summer mountain pastures under full stocking.

The trip under the circumstances was very easily made, and was devoid of the many hardships which are usually encountered, even in regions much more easily traveled. This was due entirely to the excellent provisions made for our accommodation. The traveling was done by team, except when we took pack outfits on mountain trips. (See Pls. I, fig. 2; II, fig. 2; III, figs. 1 and 2, and IV, fig. 1.) During nearly the entire six weeks we received accommodations at ranches lying along the route. Sometimes the stops were made at a ranch; at other times with the hay crews on the meadows, and in one instance with a round-up outfit that was gathering beef for the market. A total of about 700 miles was covered in this manner, through probably the most sparsely populated and one of the largest areas in the country, with no railroads or telegraphic communication.

DESCRIPTION OF THE REGION.

The greater portion of the area studied is situated in the Great Basin, and may be briefly and tersely described as a series of basins along the border of this large arid region, which receives less than 10 inches of moisture during the entire twelve months.

As would be expected, the transition from the Great Basin to the headwaters of the Columbia River is a very slow and gradual one, and the remarks which follow, while dealing especially with the portion of the Great Basin visited, apply in general to that portion of the Columbia River drainage which lies contiguous to it on the north. The main basins visited were the Alvoid Desert and the basin of the Malheur and Harney lakes. A glance at the map will show that even the river valleys are in effect basins, for they almost invariably empty into "sinks" (broad, level areas) over which their waters spread and evaporate early in the summer, leaving a broad expanse of grayish white soil with no vegetation and often deeply fissured, as shown in the lower portion of Pl. VII, fig. 1. The Quinn River Valley is simply a portion of the large Black Rock Desert basin, and a section of it in the vicinity of Quinn River Crossing does not differ materially from a similar section of the basin of the Alvord Desert.

These level desert bottoms receive considerable water in the spring of the year from melting snows on surrounding mountains. The Alvord Desert, it is said, is usually a lake varying from a few inches to a foot or two in depth at this season, the depth varying greatly, however, from day to day in the different portions of the bed, depending upon the direction and velocity of the wind. Surrounding these areas, many of which are entirely devoid of vegetation during the entire year, while others less pronounced have scattering growths of iodine weed (*Spirostachys occidentalis*) and scattering bunches of greasewood (*Sarcobatus vermiculatus*), is found a zone of greater or less extent—a few feet to several rods or even a mile in some cases—of salt grass (*Distichlis spicata*). Beyond this the greasewood again predominates, but often gives place in certain localities to the rayless goldenrod—the rabbit brush of the region (*Chrysothamnus graveolens*). Beyond the greasewood belt the soil is less alkaline, as shown by the presence of the black sage (*Artemisia tridentata*), which extends from here through the ravines and other depressions up into the mountains. On the lower foothills between the ravines, in which the black sage is the characteristic plant, the spiny saltbush (*Atriplex confertifolia*), hop sage (*Grayia spinosa*), and bud sage (*Artemisia spinescens*) are usually the conspicuous plants, especially in northern Nevada. The latter are less conspicuous to the northward. Indeed, we saw but very little of the three last named after leaving the Alvoid Desert until we reached the main stream of the Malheur River near the Harper Ranch, 40 miles above Ontario, Oreg.

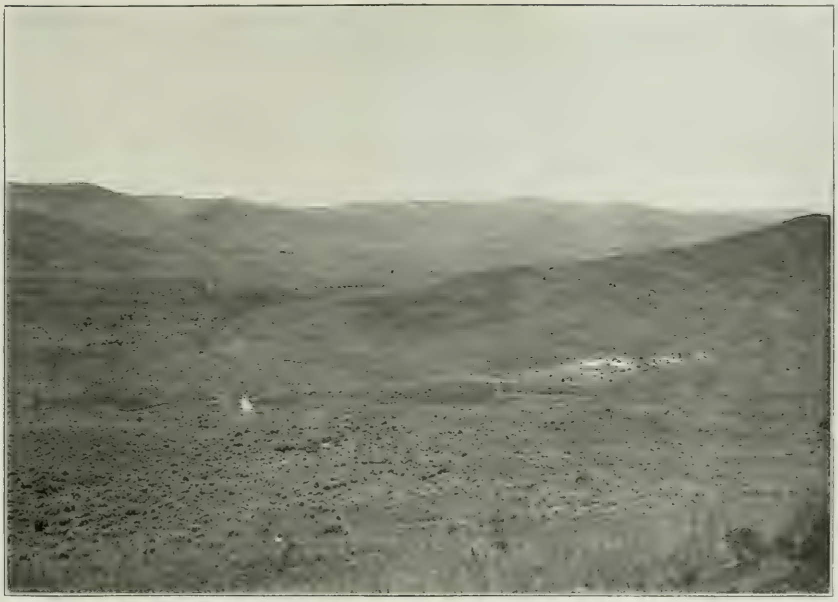

FIG. 1.—CATTLE RANGE IN BENDIRE MOUNTAINS, OREGON.

Blue grass, fescue, and black sage in foreground and a few junipers in the distance.

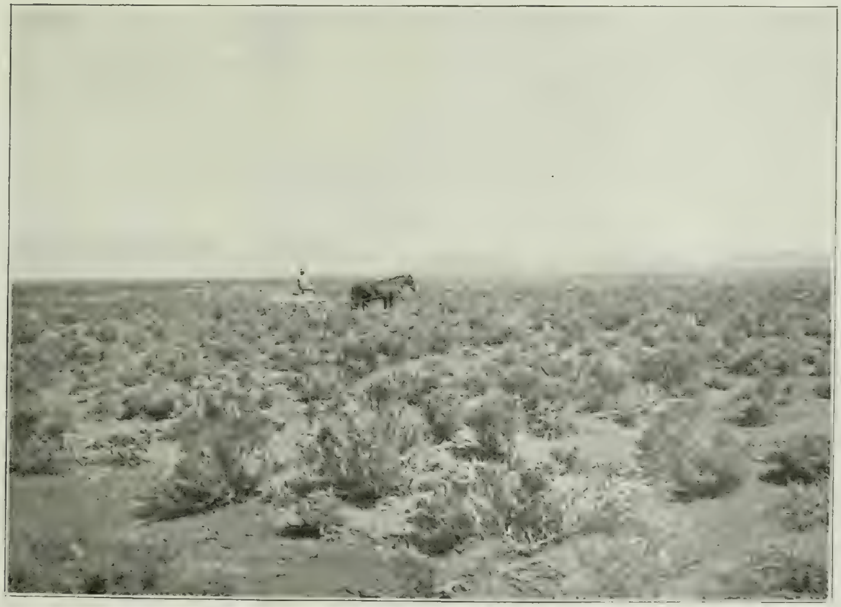

FIG. 2.—DESERT VIEW NEAR DENIO, OREGON.

Black sage, bud sage, spiny saltbush, rayless goldenrod, and hop sage shown.

PRECIPITATION RECORD FOR 1900 AND 1901.

In common with the entire Great Basin area the precipitation is very meager and occurs mainly during the winter months. The following table, kindly furnished by the United States Weather Bureau, shows for Winnemucca, Nev., and Burns, Oreg., a total precipitation of less than 7½ inches for the entire twelve months of the year 1900:

Precipitation for Nevada and Oregon.

	Nevada.				Oregon.	
	Winnemucca.		Quinn River Crossing.		Burns.	
	1900.	1901.	1900.[a]	1901.	1900.	1901.
January	0.71	1.31	....	....	Trace.	1.20
February	.69	1.87	....	2.68	1.80	1.67
March	.47	.16	....	.26	.54	.30
April	.96	.78	....	.60	1.15	.34
May	1.47	.73	....	.19	.34	.12
June	.12	.05	....	.12	.34	.15
July	.04	Trace.	....	.00	.00	.00
August	Trace.	1.16	....	.24	.17	.22
September	.22	....	....	....	.24	....
October	.74	....	....	....	.62	....
November	1.89	....	....	....	.47	....
December	.12	....	....	....	.90	....
Annual	7.43	....	....	....	6.57	....

[a] No record prior to February, 1901.

It is to be understood, of course, that the observations on precipitation are made on the lowlands. The higher levels receive much more moisture, or else the region would be a desert indeed. Observations taken on the summer range on Steins Mountains would be very instructive and show without doubt a greater precipitation for some months than for the entire year at Winnemucca or Quinn River Crossing. It is the low ranges of mountains surrounding the basins that enable the country to support even a sparse population.

The mountains for the most part are low, under 9,000 feet in altitude, and thinly wooded. A very prominent characteristic of the three ranges visited south of Burns—Pine Forest, White Horse, and Steins Mountains—is the presence of numerous narrow, steep ravines and gorges bordered by often impassable rim-rocks, and a slope to the northwest much more gentle and prolonged than that to the southeast. Indeed, the White Horse Mountains, especially, present the appearance of a huge fault which has subsequently been cut out by the action of water until there occurs a long, gentle slope, fissured by narrow ravines with very precipitous sides and bordered by perpendicular cliffs of rim-rocks.

Another very striking peculiarity which one used to Rocky Mountain areas notices immediately is the abundance of small springs which furnish but little water. This, however, is to be expected in such small and low mountain ranges. Not only does the water of Nevada not reach the ocean, but the rivers do not reach the sinks, and the small tributaries from the mountains often do not reach the main channel, for all of the water that succeeds in getting down to the fertile sage-brush areas near the river bottoms is used at the present time in irrigation. The rivers reach the sinks in the spring; the brooks, the rivers in early summer; but even the rivulets close to the base of the mountains are dry in summer or early autumn. On the advent of cool weather in the fall the waters are said to "rise" whether it rains or not. Even the diurnal fluctuation in the mountain brooks is often remarkable. One may find a brook carrying a considerable volume of water in the morning but have none whatever at 5 o'clock in the afternoon. By the next morning it will have regained its usual volume. . This was unusually conspicuous on the eastern side of Steins Mountains at the Divine and Manns Lake ranches, where observations were conducted for several days.

The only range containing pine timber south of the spur of the Blue Mountains, north of Burns, Oreg., was the Pine Forest Range near Quinn River Crossing. Here on the highest elevations is a scanty growth of pine (*Pinus albicaulis*). It is rather astonishing that we should find this isolated range having pine timber upon it, while neighboring ones, such as Steins Mountains, have no pine at all. The latter, however, have a much larger quantity of Juniper (*Juniperus virginiana*) than the former. The latter are also said to contain some balsam in one or two of the canyons, but we found none upon our route. The principal pine in the spur of the Blue Mountains which we crossed north of Burns is the bull pine (*Pinus scopulorum*). The best growth of juniper seen on the whole trip was in Steins Mountains. Even here, however, there is seldom what one may term a forest, but on the contrary, scattering trees, 10 to 18 inches in diameter are found at long intervals. Aside from the pines and juniper, the only trees of the region south of Burns are two species of poplar (*Populus tremuloides* and *P. trichocarpa*). The latter is quite abundant in canyons and deep ravines in Steins Mountains, but the former species is the important one in the other ranges visited, both in the gulches and on the high shaded slopes. Among other shrubby plants which form dense thickets, often over areas of considerable extent, may be mentioned: Mahogany (*Cercocarpus ledifolius*), service-berry (*Amelanchier alnifolia*), snow brush (*Ceanothus velutinus*), spirea (*Holodiscus dumosus*), Indian currant (*Symphoricarpos oreophilus*), shrubby cinquefoil (*Dasiphora fruticosa*), and choke-cherry (*Prunus emarginatus* and *Prunus demissa*). Along the moister areas in gulches one always finds a profuse growth of willows which are also sometimes found forming thickets on high, moist, shady slopes. In the same localities extensive growths of alder are also to be found. The willows of the entire

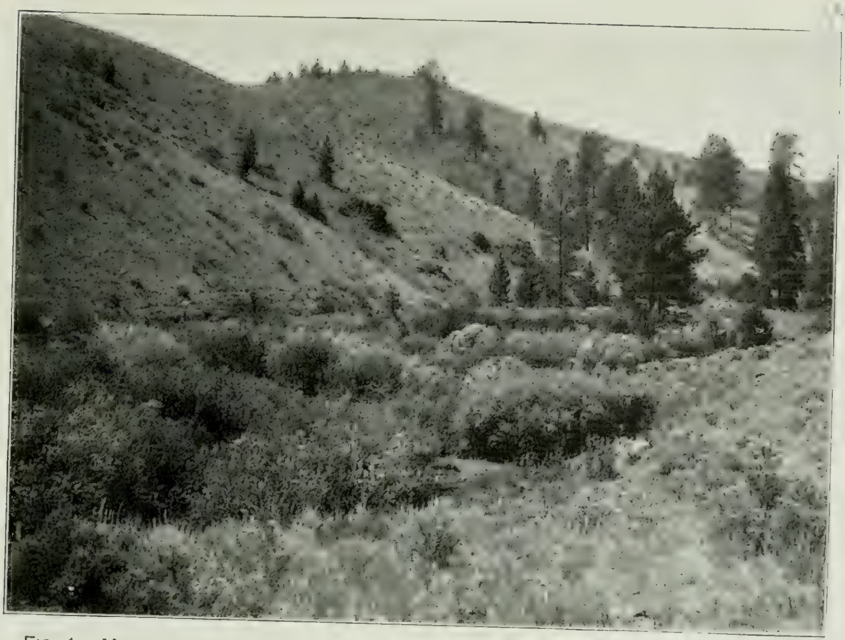

FIG. 1.—MOUNTAIN PASTURE IN BLUE MOUNTAINS ALONG CALAMITY CREEK, OREGON.

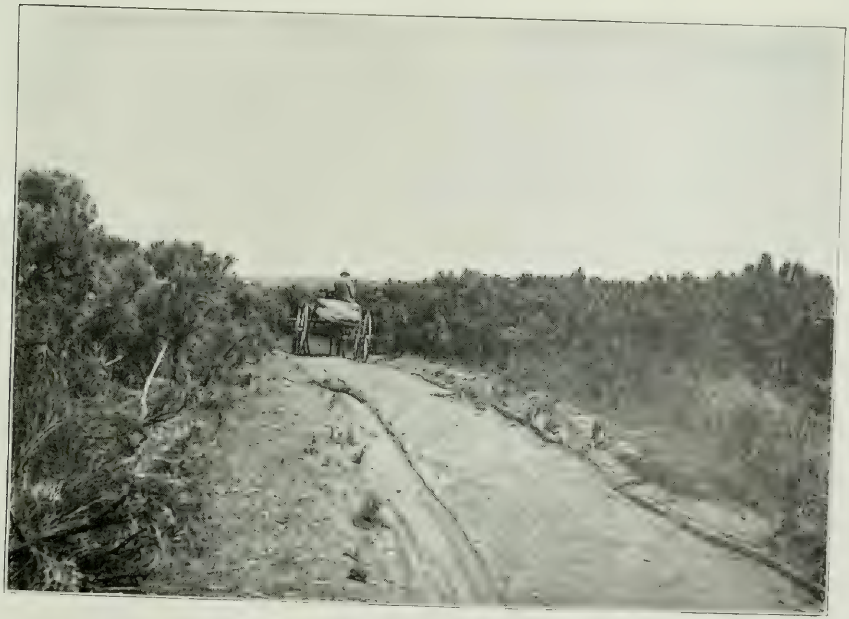

FIG. 2.—BLACK SAGE ON MALHEUR RIVER NEAR VALE, OREGON.

region are nearly all small and shrubby. They are seldom large enough for posts but are often used as stays and to a large extent in building corrals.

To casual observation the desert regions are very different from those of southern Arizona. There is a very noticeable absence of the creosote bush and the various species of *Cactaceæ*, their place being taken by the spiny salt bush (*Atriplex confertifolia*), bud sage (*Artemisia spinescens*), and black sage (*Artemisia tridentata*). Close examination, however, reveals many striking similarities. The preponderance of small animals belonging to the reptilian type, as well as the remains of an ephemeral spring vegetation, remind one of the southern deserts. This spring vegetation, which was recognizable at the time of our visit, belongs largely to the phlox, mustard, and borage families and apparently to the botanical genera *Gilia*, *Sisymbrium*, *Amsinkia*, and *Eritrichium*, a list which corresponds very closely, as far as it goes, with the conspicuous fugacious spring plants of the Arizona deserts.

THE SOILS.

An effort was made to learn as much as possible concerning the relation of the soluble salts in the soil to the development of forage crops both native and cultivated. Fifty soil samples were gathered, but owing to lack of time for their study only twenty-four were selected for analysis. A comparison of the description of the samples with the table of analyses will show that the selection was made with special reference to certain forage crops. The analyses are of value, therefore, in indicating the kind of soil upon which the best native forage plants grow, and suggest what may be expected of such areas when an attempt is made to bring them under cultivation. In a few instances analyses of soils which have baffled attempts at seeding with cultivated crops, especially alfalfa, are given. Some of the failures reported and observed are evidently due to too much soluble salts in the soil, while others are directly traceable to improper application of irrigation water.

DESCRIPTION OF SOIL SAMPLES.

No. 1.—July 16, on Humboldt River, 3 miles below Winnemucca, Nev. Deep, productive river-bottom soil, which bakes very hard when dry. It is this soil which produces fine crops of wild wheat or blue stem (*Elymus triticoides*). It is evidently very fertile, and when properly irrigated yields immense crops of hay. The sample was wet when collected, and was taken from a typical locality from which was being cut 2 tons of hay per acre.

No. 3.—July 19, near "Dutch John ranch," Quinn River Valley, Nev. Greasewood (*Sarcobatus vermiculatus*) soil which bakes very hard when dry. Probably very alkaline, but this had no crust. Large areas in this vicinity are covered with water during a portion of the winter and early spring.

No. 4.—July 21, Quinn River Crossing, Nev. Salt grass land, crusty and exceedingly hard. The crust is easily broken, rather thin and seldom white. Below this is a layer of rather mellow soil subtended by a hardpan. The crust is about one-eighth of an inch in thickness, mellow soil one-half inch and hardpan indefinite.

No. 8.—July 21, 1901, Quinn River Crossing, Nev. Giant rye-grass (*Elymus condensatus*) soil, so hard at this time of the year that it is almost impossible to penetrate it with a trowel. This sample is from the typical open areas on the Quinn River bottoms near the Miller and Lux ranch, and differs very materially from the soil which produces equally large quantities of this grass in sage-brush areas. The meadow from which this sample was taken is heavily pastured during the winter months.

No. 11.—July, 1901, near Leonard Creek ranch, about 85 miles northwest of Winnemucca, Nev. There was practically nothing growing where this sample was taken except Nuttall's saltbush (*Atriplex nuttallii*) and white sage (*Eurotia lanata*). The sample was taken from a small basin-shaped depression about 20 rods in diameter. It has a very different appearance from the typical white sage soil of the region, the latter usually growing on well-drained slopes with the spiny saltbush (*Atriplex confertifolia*).

No. 13.—July, 1901, Alder Creek ranch, about 100 miles northwest of Winnemucca, Nev., and at the western base of the Pine Forest Mountains. Meadow soil in which Nebraska sedge (*Carex nebraskensis*) grew to the exclusion of all other vegetation. This sedge invariably grows in low depressions which are flooded for a large part of the year.

No. 16.—August 1, 1901, in Nevada, near Denio, Oreg. This is considered to be the typical soil upon which this rayless goldenrod (*Chrysothamnus graveolens*) is usually found. There were but very few other shrubs or other vegetation of any kind growing where the sample was taken.

No. 17.—August 2, 1901, near Denio, Oreg. Sample taken from what appeared to be a very alkaline situation covered with a good stand of alkali saccaton (*Sporobolus airoides*).

No. 18.—August 2, 1901, near Denio, Oreg. Sample from one of the rather sandy areas surrounding and situated above the bottom of the valley. The vegetation consists of black sage (*Artemisia tridentata*), bud sage (*Artemisia spinescens*), spiny saltbush (*Atriplex confertifolia*), hop sage (*Grayia spinosa*), and rayless goldenrod (*Chrysothamnus viscidiflorus*). It is unusual to find these plants growing in this way. They are usually more or less separated and grow on different soils. It is common to find two or three of them together, but the writer has never seen them growing so intimately mixed anywhere else.

No. 22.—August 6, 1901, Alvord Desert, Oregon. This is what is known in the region as "self-raising ground." It presents a peculiar appearance, inasmuch as the soil blisters and is mellow on top, while the subsoil may be moist, as was the case where this sample was taken, or it may be exceedingly hard when it becomes dried out. No salt was visible where this sample was taken, neither was there any vegetation of any kind. The soil is covered in late winter and early spring with about 6 inches of water. This evaporates early in the season, when the ground becomes dry, hard, and fissured.

No. 23.—August 6, 1901, on the Wild Horse Ranch, near Andrews, Oreg. The sample was taken from the center of a large area of salt grass (*Distichlis spicata*). The soil is very hard but has no salt visible upon it. The grass in this locality was covered with a gummy, acid secretion. This does not appear on the base of the culms near the ground, but on the upper, green, and vegetative portion of the plant. It is a very peculiar characteristic of salt grass over large areas in eastern Oregon. It was met with first in small areas at Quinn River Crossing, Nev., and was subsequently observed at Divine's ranch on the edge of the Alvord Desert, and also on the Malheur Lake bottom south of Burns. The secretion has a gummy, sticky consistency under ordinary temperatures, but during hot weather, when the samples were collected, it deliquesced very readily when carried in a vasculum. The presence of the secretion is very noticeable the moment one attempts to walk through an area of grass covered with it, on account of the impediment which it offers. One's clothing soon becomes covered with the gummy substance. The areas upon which it appears, while often very large, have quite definite boundaries, and one area may be entirely free from this secretion while another in close proximity may contain large quantities of it. No difference was observed between soil characteristics of the affected and unaffected areas. The largest quantity of deposit and the largest extent of grass affected was on the meadows near Andrews, Oreg.

No. 24.—August 7, 1901, Wild Horse Ranch, near Andrews, Oreg. Garden soil irrigated from a spring of pure water,[a] located on an alkali knoll, which produced nothing but salt grass. The garden was located about 10 feet lower than the spring. A black crust is often seen on the ground and along the ditches, but in spite of this strongly alkaline appearance good vegetables, potatoes, onions, and beets were raised on the soil.

No. 25.—August 7, 1901, Wild Horse Ranch, near Andrews, Oreg. This is a sample of a black deposit from the edges of the irrigating ditch carrying water spoken of in sample 24. A black crusty deposit appears all along the ditches.[a]

No. 26.—August 7, 1901, Wild Horse Ranch, near Andrews, Oreg. Soil from which this sample was taken contained a very conspicuous growth of rayless goldenrod (*Chrysothamnus graveolens*) with alkali grass (*Puccinellia airoides*) and salt grass (*Distichlis spicata*) covering from two-thirds to three-fourths of the ground between the bushes.

No. 29.—August 13, 1901, Divine's ranch, 15 miles northeast of Andrews, Oreg. Sample is from the lowlands, some distance from the Alvord Desert. Vegetation where sample was taken consists of small cord grass (*Spartina gracilis*) and some salt grass (*Distichlis spicata*). There was a slight crust of salt on the surface.

No. 32.—August 13, 1901, near Divine's ranch, on swamp meadow belonging to Manns Lake Ranch, about 20 miles northeast of Andrews, Oreg. There was no vegetation where the sample was taken. There was a thick (one-fourth of an inch) blistery crust of white or sometimes yellowish salt on the surface. The soil below this was black or brown-black, pasty and moist. It was of the consistency of putty and situated some distance from a small greasewood area on a swamp meadow. A small packet of surface salt is included.

No. 33.—August 13, 1901, near Divine's ranch, about 20 miles northeast of Andrews, Oreg., on a swamp meadow belonging to Manns Lake Ranch. This soil produced from 2 to 2½ tons of hay per acre of prairie bulrush (*Scirpus campestris*). It was very hard, dry, and badly cracked (Pl. VII, fig. 1). This sample was taken within 15 yards of sample No. 32. There was a narrow strip, 4 or 5 feet wide, of salt grass intervening between the bare area where No. 32 was taken and this fine growth of the bulrush.

No. 34.—August 14, 1901, Juniper Ranch, about 20 miles north of Manns Lake, Oreg. Boggy, sedgy, meadow soil, very characteristic over large areas in this region. Two or three species of sedges, a little clover, and moss constitute the principal vegetation.

No. 38.—August 15, 1901, Malheur Lake bottoms, near Windy Point, Oreg. The sample is from one of the large squirrel tail grass (*Hordeum jubatum*) areas so characteristic on the open range to the east and north of the lake. The soil is porous, dark in color, and has the appearance of being rich and productive. It is usually slightly lower than the surrounding salt grass areas and is often spotted or even covered with a dense growth of rayless golden rod, with which the squirrel tail grass is mixed. Where the sample was taken there was no vegetation but squirrel tail grass.

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[a] Analysis of a sample of the water subsequently furnished by Foreman Arthur Barnes verifies this statement, there being but 19.3 parts solids per 100,000. The alkali along the ditches was evidently from the soil between the spring and the cultivated area.

No. 40.—August 17, 1901, Malheur Lake bottoms, Island Ranch, about 15 miles south of Burns, Oreg. Soil where awned sedge (*Carex aristata*) grew to the exclusion of all other vegetation. This appears to be rich soil, and certainly produces magnificent crops of this important forage plant.

No. 41.—August 17, 1901, Malheur Lake bottoms, Island Ranch, about 15 miles south of Burns, Oreg. The soil from which this sample was taken produced in restricted areas a ton to a ton and a half per acre of yellow top (*Calamagrostis hyperborea americana*). The localities in which this grows are usually well drained, and occur on slight elevations immediately surrounding the depressions where water remains until about the middle of July.

No. 43.—August 22, 1901, Agency Ranch, on North Fork of Malheur River, near Beulah, Oreg. Meadow soil, where alfalfa, timothy, and redtop sown last spring have made a fine growth. (See next sample.)

No. 44.—August 22, 1901, Agency Ranch, on North Fork of Malheur River, near Beulah, Oreg. The soil where this sample was taken differed but little in appearance from the previous one, but it contained no forage plants, and the seeds sown last spring failed to grow. This meadow is the most spotted one seen, although similar conditions on less extensive areas are frequent. Small areas with good stands of timothy, redtop, and alfalfa are common, while a few feet away there is nothing to be found but a weedy development of a couple of the annual saltbushes, mainly *Atriplex truncata*, and one of the western blights (*Dondia depressa erecta*). In some places there is a little salt visible on the surface of the bare or weedy areas, but the subsoil, to all appearances at least, is precisely the same as that which a few feet away produces a good stand of the forage plants sown.

No. 50.—August 23, 1901, Harper Ranch, on Malheur River, 40 miles above Ontario, Oreg. The field from which this sample was taken was sown last spring to alfalfa. Over the greater portion of it a fine stand was secured, but in one corner, which was considerably lower than the remainder of the field, water collected from the two irrigations which it received. There was no alfalfa whatever here, but a fine volunteer crop of barnyard grass (*Panicum crus-galli*) appeared instead. (Pl. XVI, fig. 1.) This volunteer crop would yield about 2 tons of dry feed per acre.

PARTIAL ANALYSES OF SOIL SAMPLES.

The following table of analyses of the samples of soils collected on the trip and the remarks thereon were kindly furnished by the Bureau of Soils of this Department:

Partial analyses of soil samples.

Number of sample.	Percent soluble in water.	Carbonate (CO_3).	Bicarbonate (HCO_3).	Chlorids (Cl).	Sulphates (SO_4).	Phosphates (PO_4).	Nitrates (NO_3).	Borates (B_2O_7).	Carbonate of lime in soil.	Remarks
1	0.13	......	......	......	......	......	......	......	Small amount.	Not harmful amount of salts.
3	4.00	0.00	0.07	0.31	2.41	Trace.	0.00	0.00	....	Sulphates (white alkali).
4	3.00	.19	.26	.76	.16	0.07	.00	.00	....	Carbonates and chlorides (black alkali).
8	.04	......	......	......	......	......	.00	.00	None	Not harmful amount of salts.
11	.06	......	......	......	......	......	.00	.00	Small amount.	Do.
13	.03	......	......	......	......	......	.00	.00	None	Do.
16	.08	......	......	......	......	......	.00	.00	Small amount.	Do.
17	4.50	.00	.06	.37	3.28	Trace.	Trace.	.00	None	Sulphates (white alkali).

Partial analyses of soil samples—Continued.

Number of sample.	Per cent soluble in water.	Carbonate (CO_3).	Bicarbonate (HCO_3).	Chlorids (Cl).	Sulphates (SO_4).	Phosphates (PO_4).	Nitrates (NO_3).	Borates (B_2O_7).	Carbonate of lime in soil.	Remarks.
18	0.02	......	......	....	......	....	0.00	0.00	None	Not harmful amount of salts.
18^1	.03	......	......	....	......	....	.00	.00	.....do	Do.
18	.05	......	......	....	......	....	.00	.00	.....do	Do.
22	4.00	0.20	0.50	1.62	0.19	0.07	.00	.00	Large amount .	Carbonates and chlorids (black alkali).
23	.60	.14	.17	.03	.02	.04	.00	.00	.....do	Carbonates (black alkali).
24	.13	......	......	....	......	....	.00	.00	Small amount .	Not harmful amounts of salts.
25	1.60	.36	.46	Trace.	.01	.03	.00	.00	.....do	Carbonates (black alkali).
26	.52	.12	.24	.03	.04	.04	.00	.00	Large amount .	Do.
29	.50	.11	.14	.02	.04	.00	.00	.00	.....do	Do.
32	2.20	.48	.29	.02	.28	.08	.00	.00	.....do	Carbonates and sulphates.
32½	Crust.	16.19	28.46	1.05	12.75	.18	.00	Trace	.....do	Do.
33	.70	.12	.39	.03	.21	Trace.	.00	.00	.....do	Do.
34	.16	.00	.12	.02	.01	Trace.	.00	.00	None	Not harmful amounts of salts.
38	.35	.00	.27	Trace.	.02	Trace.	Trace.	.00	Large amount .	Do.
40	.14	......	......	....	......	....	....	......	.....do	Do.
41	.35	.00	.25	.01	.02	.04	Trace.	.00	.....do	Do.
43	.25	.00	.19	.00	.01	.00	.00	.00	Small amount .	Do.
44	.50	.03	.36	.03	.02	.07	Trace.	.00	.....do	Carbonates (black alkali).
50	.25	.00	.18	Trace.	.03	Trace.	.00	.00	.....do	Not harmful amount of salts.

Only partial analyses are given, since they are sufficient to determine the kind and nature of the soluble salts.

The analyses of the water soluble component were made according to the conventional formula adopted by the Bureau of Soils: that is, to analyze the portion taken out of a soil by water, when the soil is kept in contact with twenty times its weight of water until equilibrium has been reached.

It has been found in the experience of the field parties of the Bureau of Soils that 0.6 per cent of soluble salts is a dangerous amount in a soil if there be no carbonates present. When soluble carbonates are present, 0.4 per cent may be regarded as the limit of endurance for cultivable crops. These limits have been established by the use of the bridge or field method for determining soluble material in the soil. The method of leaching, such as has been used in the accompanying analyses, will frequently give higher figures than those stated above as the limiting values for cultivable plants.

It appears from Mr. Griffiths' notes, together with these analyses, that salt grass (*Distichlis spicata*) is a black alkali plant. This bears out former observations and work of the staff of the Bureau of Soils.

The analyses show that several very important native forage plants grow on soil which is decidedly alkaline and which would in all probability not be easily brought under cultivation. The use of native species of plants as indicators of fertility of soil is recognized by all ranchers in a general way. This, however, is more especially true of the black sage than of any other plant. It is universally recognized that soils which produce luxuriant growths of this shrub are fertile and are especially well adapted for the cultivation of alfalfa, the main crop of the region. On the contrary, grease-wood soil is seldom cleared up and cultivated. When, however, it is desirable to bring the latter under cultivation, it is said that timothy is the most certain crop, and that it thrives best on such soil with frequent light irrigations rather than with large amounts of water at infrequent intervals, as is usually applied to alfalfa.

The analyses of samples 43, 44, and 50 are especially instructive. It will be seen that sample 43, taken where seed germinated well, and sample 44, where it failed entirely, although only 15 feet apart, differ considerably in the amount of soluble salts which they contain. This difference, although only 0.25 per cent, is sufficient to place sample 44 in the class of soils containing dangerous amounts of alkali. This analysis also shows, as far as the analysis of a single sample can, that there is no appreciable difference between the resistant powers of alfalfa and timothy, although, as stated above, there is a popular belief that such is the case. Further investigations along this line would be profitable. Sample 50, on the contrary, does not appear to contain soluble salts in harmful amounts, although a stand of alfalfa was not secured on the land last spring. The failure here appeared to be due, as was suspected, to improper drainage.

FORAGE PLANTS GROWING ON ALKALINE SOILS.

The following table contains a condensed list of those forage plants which were found growing in soils containing soluble salts in quantities sufficient to be deleterious or dangerous to cultivated crops:

Forage plants growing in alkaline soils.

Number of soil sample.	Name of plant.	Per cent of soluble salt.	Kind of alkali.
3	Grease wood (Sarcobatus vermiculatus)	4.00	White.
4	Salt grass (Distichlis spicata)	3.00	Black.
17	Alkali saccaton (Sporobolus airoides)	4.50	White.
23	Salt grass (Distichlis spicata)	.60	Black.
26	Alkali grass (Puccinellia airoides)	.52	Do.
29	Small cord grass (Spartina gracilis)	.50	Do.
33	Prairie bulrush (Scirpus campestris)	.70	Do.
44	Utah saltbush (Atriplex truncata)	.50	Do.

HANDLING OF STOCK.

As is inevitably the case in all open-range stock raising, the methods of operation are rapidly changing. Where a few years ago cattle were almost unprovided for during the entire winter and were taken from the range directly to the eastern markets, they are now fed from two to four months of the year and are almost invariably fattened before being slaughtered. This change is being brought about by two causes which are very intimately related to each other. The persistent home seeker has explored these vast areas and taken up land under his rights as a citizen wherever a favorable spot appeared. At the present time the tillable areas where water is convenient and, therefore, under conditions of nature the most productive in the unim-

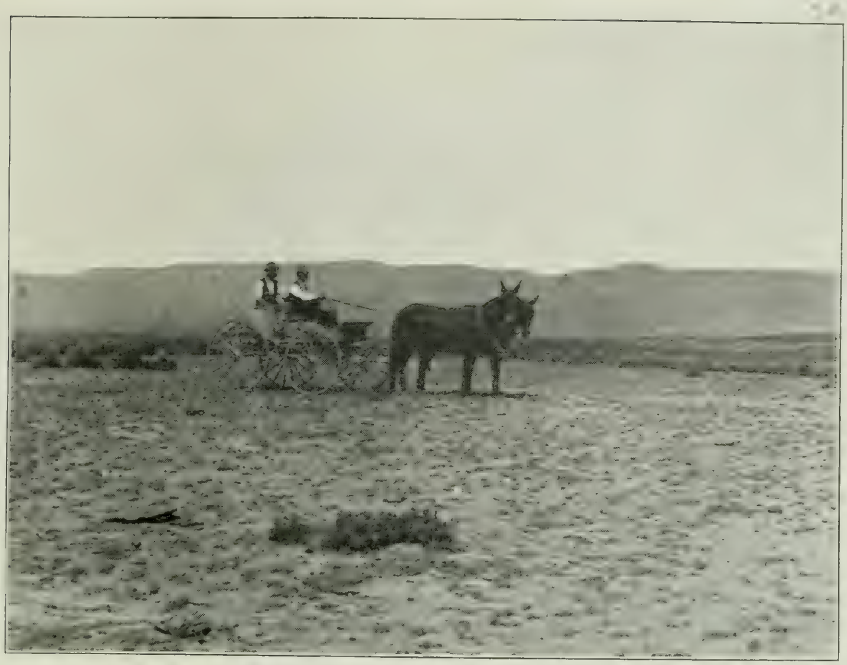

FIG. 1.—GRAZED NUTTALL'S SALTBUSH, WESTFALL, OREGON.

No other vegetation shown in foreground except one bunch of cactus.

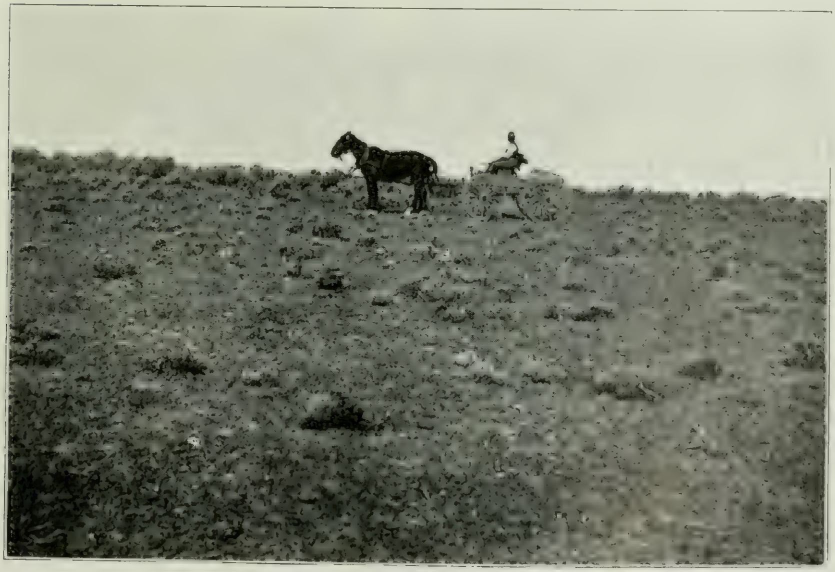

FIG. 2.—BLACK SAGE (ARTEMISIA RIGIDA) GRAZED, WESTFALL, OREGON.

Common black sage (Artemisia tridentata) in background.

proved condition, have been made the bases for ranches. These favorable areas have consequently been cut out of the general range source of supply. The second cause is dependent upon the first and results from the overstocking of the range, giving the cattle but little to feed upon during the winter. They therefore must have provision made for them. In portions of Montana, Wyoming, and western South Dakota it is customary to fence large areas of land on the general mesa or prairie in order to protect the range until winter sets in. No hay is cut in these fenced fields. The grass simply dries up in the fall and the cattle graze it during the winter. In northern Nevada and southeastern Oregon, however, the fenced areas occur on the bottom lands, and they are made to serve the double purpose of furnishing a crop of hay during the summer and pasturage during the winter. Indeed, many of these fields were being pastured while we were in the region in August. But more will be said concerning this later. The reason for this difference in the use of the pastures in the two regions is a simple one and results from local and natural conditions. The mountain regions as a whole are unsuitable to winter pasturing, and the desert mesa in this region furnishes so little feed that it scarcely pays to fence and protect it during the summer. The only available sources of pasturage during the winter, therefore, are the bottom lands. They are also the only available native hay lands, and are therefore forced to furnish both winter pasturage and hay. The result of this double drain upon the land is too well known to need any extensive comments. The result is just what one would expect—both the pasture and the hay crop are rendered inferior by such treatment.

According to information received from ranchers scattered all the way from Winnemucca to Ontario, the feeding season begins about the 1st of December and continues until the last of March. During the remainder of the season the cattle "rustle" their living. Full feeding, however, does not begin until after Christmas. From this time on about two-thirds of the cattle receive a full ration of hay, the remaining third finding their own living in the lowland pastures among the tule (*Scirpus lacustris*) and willows and in other localities where it was impossible or unprofitable to run a mower during the previous summer. Of course, there is some growth of grass on the meadows which were cut, and this also is pastured down closely. In this way all cattle are provided for during the winter. They are either pastured in the fields or fed hay, as their condition appears to demand. Usually the steers and dry cows "rustle" for themselves in these pastures; but the majority of the cows and all the calves are fed, the pasture herd being continually worked over during the winter, for the purpose of selecting those that need more feed than they are able to secure in the meadows.

Sheep are usually wintered on the desert. They feed at this season to a very large extent on desert shrubbery. Being able to subsist on this kind of a ration better than cattle, renders them much more easily provided for. Indeed, as near as we were able to learn from the herders and ranchers, sheep receive hay for from only two to four weeks through the entire winter in the southern portion of the area traversed. Being able to subsist on even the black sage (*Artemisia tridentata*) for a few days, they are much less subject to loss during a season of severe weather, especially as they have a herder with them constantly, who is able to move them from place to place and thus secure the best feed available. One man usually takes care of from 2,000 to 3,000 sheep. One herder in the White Horse Mountains informed us that his flock was never fed over two weeks during the winter; others placed the feeding period at four weeks, while we were informed at Ontario that in that vicinity they were often fed some hay for two months.

The summer feed of both cattle and sheep is obtained from the open range on the foothills and mountains. The sheep wintered on the deserts begin to move upward as soon as the vegetation appears in the spring. They follow the development of the green feed from the foothills up to the snowdrifts, and finally work their way down again by easy stages when autumnal storms begin to threaten. The sheep, being close-herded, clear the ground over which they pass of vegetation much more closely than the cattle which run at large with practically no care, and consequently scatter in small herds of six to twelve animals. This, together with the fact that sheep eat plants that cattle will not, constitutes the main distinction between the effect of cattle and sheep on range pastures. If allowed to run at large as cattle do, and consequently scatter in small flocks, as they naturally would, the evil effect of absolutely cleaning off large areas by close grazing, and the pulverizing of extensive tracts of ground in the region where they tramp in closely packed herds during the heat of the day, and still more effectively in the bedding-down places at night, would be largely overcome. But this method of handling sheep could not of course be practiced because of the presence of dogs and wild animals which would in a short time exterminate the flocks.

The cattle, although allowed to run at large, are looked after to some extent during the summer. They also are kept in the mountains as much as possible. When they return to the lowlands, where they were fed during the previous winter, either on account of short feed or the sheep herder's dog, they are forced up again as soon as their numbers on the lower areas become at all conspicuous.

The feeling between the "cattleman" and "sheepman" is here, as in the majority of the open range regions, often a very bitter one. The "sheepman" having a herder to look after the interests of the flock has a decided advantage over the "cattleman," whose interests

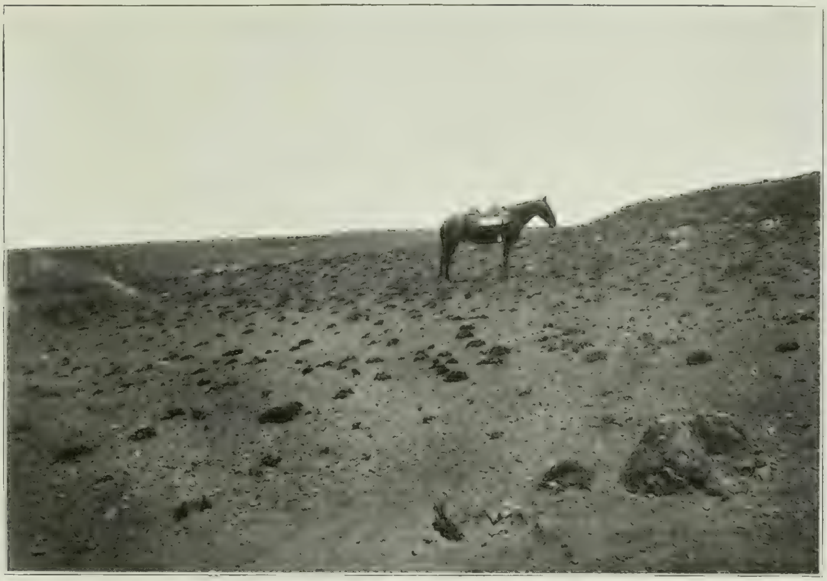

FIG. 1.—A DEPLETED RANGE IN STEINS MOUNTAINS, OREGON.

Objects in foreground are dead stools of sheep fescue.

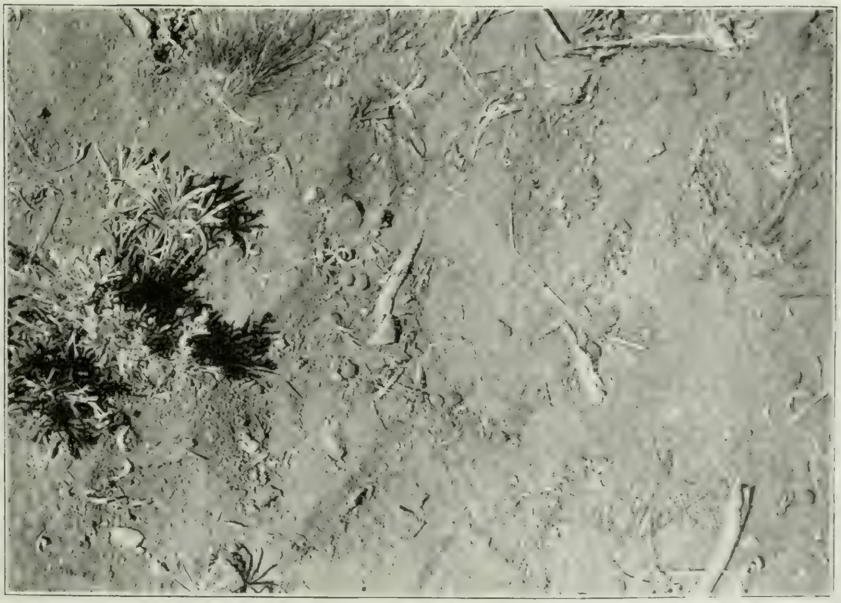

FIG. 2.—SURFACE VIEW OF SOIL IN PINE FOREST MOUNTAINS, NEVADA, AFTER CLOSE GRAZING BY SHEEP.

have but little care during the summer. The sheep herder claiming as good a right to the free grass of the range as anyone, naturally drives his flocks where the best feed is found; and, on account of the necessity of securing green fodder for the lambs, he travels up the mountains in the spring as fast as the feed and weather conditions permit and returns to the desert areas again during the winter, often close to the possessions of the "cattleman." The latter claims that on account of his owning property and paying taxes for the support of the local government, which the sheep owner often does not, he has a right to the free range in his vicinity.

The greatest difficulty and hardest feelings relate to the migratory sheep bands which come, not only from neighboring counties, but occasionally from neighboring States, and deprive the settlers of the good mountain pastures which they consider belong to them on account of their residence, their holdings, and their support of township and county governments. The sheep industry, in the southern portion of the region especially, is in a peculiar condition. All of the water on the fertile lowlands was taken up in early days by cattle interests, and the cattlemen looked upon the use of the mountains for grazing purposes as a natural right. In recent years sheep have been driven from great distances both east and west into the mountains to take advantage of the luxuriant pastures of blue grasses and fescues. Another element entering largely into the controversy is what is denominated the alien sheep interests. It is said that a very large proportion of the sheep in the region belong to Basques, who own no land, and who in many cases are not citizens.

THE RANGE.

It would be very difficult indeed to find a range in which the pasture zones as well as the general floral areas were better marked than they are in the southern portion of the territory covered. The vast barren tracts in the basins are bordered by the alkali-inhabiting vegetation, such as salt grass, greasewood, and others of similar habits. These give place beyond to shrubby plants, such as the black sage and the salt sages, described elsewhere. The former occupy the lower portions of the general mesa regions and extend into the foothills and mountains. The prevailing characteristic of the foothills and mountain regions, however, is the presence of the nutritious grasses which furnish the summer feed for the numerous herds of cattle and sheep. While the species of grasses in this region are numerous, there are about four which furnish the largest quantity of feed. The most important of these is Buckley's blue grass (*Poa buckleyiana*), which grows at the lowest altitude in the foothills and extends into the mountains. On the steeper embankments, rocky slopes, and canyon sides are usually found large quantities of Wheeler's blue grass (*Poa* *wheeleri*) and bunch wheat grass (*Agropyron spicatum*). Beyond the blue-grass zone of the foothills and lower mountain areas occur the finest pasture lands of the region. These, while in all probability furnishing no more nutritious grass than the foothills, are much more attractive and in some respects much more important than the former, owing to the fact that they are more often free from shrubbery and other plants with little or no forage value, and consequently furnish a larger quantity of feed per acre. This is the sheep fescue area, and this important grass in one of its two principal varieties grows often to the exclusion of all other forms of vegetation.

The first of these zones, that including and immediately surrounding the barren basin bottoms, is greatly modified in certain localities. Wherever there is a small valley contributing water to the basin or river bottom, the general alkalinity of the region has been neutralized by the beneficial action of the rich sediment brought down from the mountains, or otherwise counteracted to such an extent that the soil has been made very rich and productive. By these methods delta-like areas have been built up in the lower valleys or ravines or in borders of greater or less width along the river courses. It is in these areas that the ranches of the region are built, and it is upon them that the region is dependent for its winter feed, consisting sometimes of excellent but often very ordinary crops of native hay and forage plants. On the more elevated portions of the lower valleys where the drainage is good and where, under natural conditions, the black sage (*Artemisia tridentata*) predominates, is located the best soil, as experience has demonstrated, for the culture of alfalfa, the main cultivated hay crop, and, indeed, about the only crop of any kind upon which much dependence is placed.

One may therefore recognize three typical forage zones or areas, namely: Lowlands, including river bottoms, and low areas in basin-shaped depressions furnishing winter feed in the shape of pasture and hay, but more especially the latter at the present time; the mesa, including the intermediate zone between the lowlands and the next named, furnishing but little feed except browse, its main resources consisting of shrubby plants, such as true sages, salt sages, white sage, and red sage; and the highlands, including the foothills and mountain region, which furnishes practically the entire summer pasture. The general appearance of some of the lowland areas, with their characteristic vegetation, are shown in Pls. II, fig. 2; XIII, fig. 2; XIV, fig. 2, and XV, figs. 1 and 2. The surface soil on the mesa region is for the most part uncovered, the shrubby vegetation usually being much scattered and only from 2 to 3 feet high. Some idea of this region can be gained from Pls. I, fig. 2, and III, figs. 1 and 2. It may be a broad, gentle, sloping plain, as shown in the first figure, or exceedingly broken and fissured by deep ravines. The highland, including, as stated above, both foothills and mountains, while producing a much larger amount of feed than the mesa, has by no means its entire surface covered with vegetation. The shrubbery has been spoken of elsewhere. The black sage (*Artemisia tridentata* and *A. arbuscula*) growing in scattered bunches, have here, unlike the mesa region, a considerable growth of scattering bunches of grass between them. The grasses are nearly all of the perennial varieties, and consist mainly of blue grasses, sheep fescue, and wheat grass, all of which grow in bunches and form but little, if any, turf. Pls. I, fig. 1; II, fig. 1; IV, fig. 1; V, figs. 1 and 2; VI, fig. 1, and XIII, fig. 1, give fairly typical representations of the grazing areas on the uplands.

A careful study of the forage plants of one of the basins of this region, with an equally exhaustive soil study covering a period of nine or ten months and extending from the bottom of the basin to the top of the mountains, would prove not only of great scientific interest, but would undoubtedly throw very important light upon many features of the forage problems as they exist throughout this general region. As a suitable locality we might mention the Alvord Desert basin, where the distance from the desert lake bed in the bottom of the basin to the line of perpetual snow in Steins Mountains is not too great to be covered on foot in a single day, while extensive deposits of borax are located in the same depression about 20 miles away. A thorough correlation of soil conditions with the development of forage plants could be easily made here and would doubtless apply to large areas of country. A study of the conditions best suited to the development of the characteristic forage plants could easily be made, and the rôle of the shrubby vegetation in the economy of stock raising could be accurately determined, a point upon which there is altogether too little accurate information at the present time. A comparative study of the native clovers upon newly irrigated sagebrush soil and their native habitats in the lower, boggy, and almost peaty areas, and the rapidity of their spread into newly irrigated areas contiguous to their natural habitats, would be very instructive. A comprehensive study of the condition under which these valuable forage plants develop to the best advantage would be of great economic importance. Whether they develop best when growing alone or in combination with more rigid plants, which assist in their support, and the quantity of feed which they produce could be determined here by observation of their habits under natural conditions. No better locality could be selected for the study of the specific distinction of two of the valuable groups of range grasses, namely, the sheep fescues and that group of blue grasses closely related to Buckley's blue grass. A question of much economic interest to this region, as well as to all that grazing area to the south and southeast, relates to the value of the early weedy plants as cattle food. A knowledge of these is necessary—what they are and to what extent they are eaten by cattle and sheep. But little investigation has been made of the desert ranges in spring and early summer, when they yield much feed consisting of short-lived annual plants differing very materially both in kind and quality from the grasses which grow at this season in regions of more copious and equable rainfall. It is well known that Indian wheat (*Plantago fastigata*), Nuttall's vetch (*Astragalus nuttallii*), and similar weedy plants play a very important part in the economy of stock raising in the deserts of the Southwest. Here also we have a desert range which produces a large and comparatively abundant crop in early spring, forming at least much sheep pasture, concerning which but little is known aside from the information derived from an occasional statement and description by observing ranchers. These are some of the economic questions that might be studied on local representative areas like this one. The purely scientific questions, whose bearing upon practical ones seldom can be properly appreciated, are altogether too numerous to be considered.

RANGE CONDITIONS.

The condition of the lowland pastures and meadows has been briefly spoken of elsewhere. These areas are at the present time almost invariably the property of private individuals, and consequently under their direct control and management. The bottom lands which still remain open to settlement are so situated that no water is available for their irrigation, the control of water in the streams being in the hands of the owners of the first ranches settled. Inasmuch as the supply is scarcely sufficient for the use of these first comers, there is no inducement to the prospective settler to take up the other open-range bottom land, although it may be equally as productive. If convenient to water holes, these areas are always closely grazed and present a very unpromising appearance. No open-range lowland was seen on the whole trip which had much feed upon it excepting that consisting of the tough and persistent salt grass. Everything else had been cropped closely. In many localities cattle were apparently subsisting on this grass.

The more favored and protected areas under private control, although altogether too closely pastured, fare much better than the open range. As stated before, these furnish the native hay of the region during the summer and the pasturage of the strong cattle during the winter. The principal feed is found, not on the areas actually cut, but among the willows, along ditches, and in low swampy areas which remain uncut. These, although usually small, amount to many acres in the aggregate on seven or eight square miles of meadow. The shrubbery and tule (*Scirpus lacustris*) also furnish shelter during severe weather. It is needless to say that these areas are taxed to their full capacity. A piece of ground from which a crop of hay is removed during the summer will not usually maintain its productiveness in any region if every particle of vegetation remaining is pastured off during the fall and winter seasons. It is only under conditions of the most favorable

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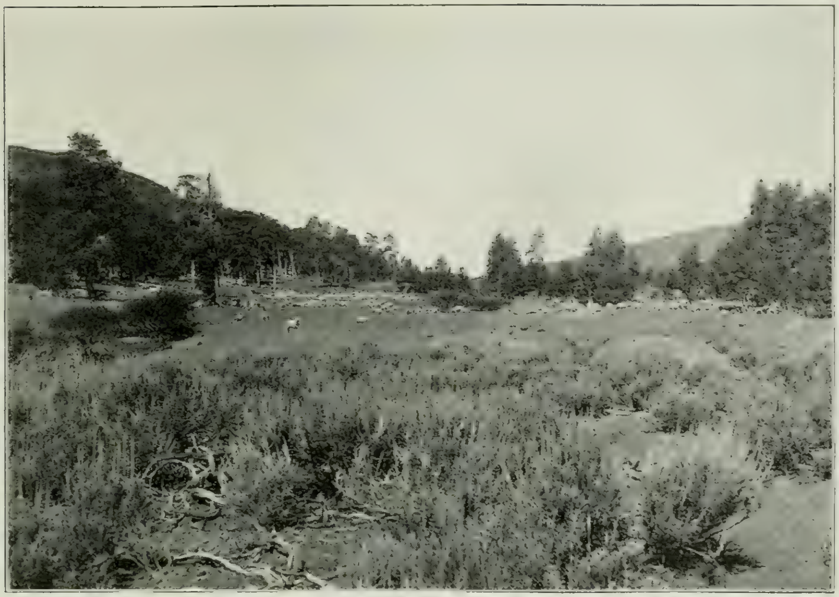

FIG. 1.—SHOWING HABITS OF SHEEP DURING THE COOL MORNING, STEINS MOUNTAINS, OREGON.

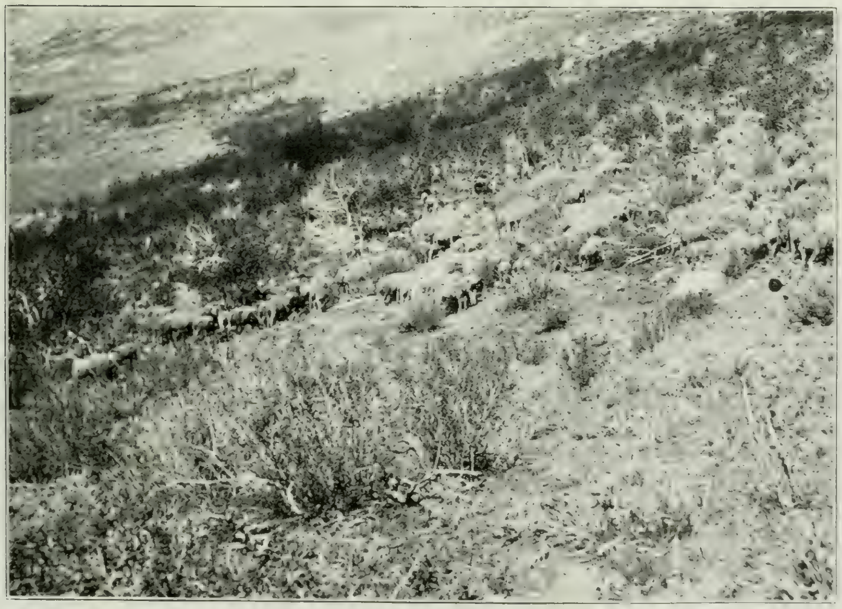

FIG. 2.—SHOWING HABITS OF SHEEP DURING THE HEAT OF THE DAY, PINE FOREST MOUNTAINS, NEVADA.

supply of moisture that the continued yield can be maintained. No more convincing evidence of the deterioration of these meadows in recent years was found on the whole trip than that furnished on the Alder Creek ranch, at the base of Pine Forest Mountains. Here the native hay meadow consists of an elongated, comparatively narrow basin extending toward the desert from the mouth of a canyon leading into the mountains. The remains of old stackyards were found for 5 or 6 miles down this meadow from the ranch. They were scattered at short intervals. At one time these were built to surround stacks of hay cut on these meadows, but they were all unused this year, except those nearest the source of water supply from the canyon.

The shortage of the native hay crop here is influenced largely by the fact that the water has been used up in late years in the irrigation of alfalfa, as well as by overstocking. This is an important factor in the modification of the conditions on all of the native hay lands. The water has been turned from its natural course, and, instead of irrigating the meadows as it once did, it is used to a large extent in the irrigation of the land which is situated just above and which naturally produces nothing but black sage (*Artemisia tridentata*). The packing of the soil by the trampling of large numbers of cattle during the fall and winter also has a very marked influence on the hay crop. The soils are as a rule unusually hard and stiff, and this condition is aggravated by the constant trampling of the cattle. One practice decidedly beneficial is the feeding of the hay on the ground which produces it. This results in returning the manure to the land and compensates in a measure for the crop taken off. The fact that the meadows have poor drainage serves to keep the refuse upon the land where it will soak into the soil during the spring-flood season.

The injury to the mesa from overstocking is largely local. The shrubbery is usually not relished as much, and consequently is not grazed as closely as the grasses. The most conspicuous desert shrub is the black sage brush, which is not eaten except in extreme cases, even by sheep. The spiny saltbush (*Atriplex confertifolia*) and hop sage (*Grayia spinosa*) usually bear evidence of browsing, but not to any injurious extent. The greasewood which in localities is even more conspicuous than the black sage is, as far as observed, never injuriously grazed, the main use that stock make of it being that of licking up the fallen leaves. This is true to some degree of the spiny saltbush and the hop sage, but these are also browsed. The shrubby mesa plants which have suffered most from overstocking are three in number. The red sage (*Kochia americana*) appears to be always closely cropped during the winter, although not eaten to any extent during the summer. Bud sage (*Artemisia spinescens*) almost invariably bears evidence of cropping, but it is probably eaten much more extensively by sheep than by cattle. The value of white sage as food for both cattle and sheep is well known and, as would be expected in a region of such short pasturage, it is very much injured by overgrazing. According to the best information we were able to get, this plant furnished a very large amount of feed on the mesa region at one time, especially to the south of the Alvord Desert. The only place where we found it in sufficient quantity to be of any great value was in the vicinity of the upper end of the Black Rock Desert, between Leonard and Bartlett creeks. It is common enough in the vicinity of Quinn River Crossing, but either on account of close grazing or drought it made but little growth this year. As seen on this trip the plants consist of only a stump and a few shoots 6 to 10 inches long. Last year's growth was invariably completely grazed off.

Inasmuch as the best grazing areas are on the highlands, the principal interest pertains to these. Representative areas of six ranges of mountains were carefully studied at the important transitional stage in the history of all ranges, when the grasses were ripening. This process occurred much earlier than usual this year according to the most reliable information obtainable. Special trips were taken into the Pine Forest, Bartlett Peak, White Horse, and Steins mountains, and a spur of the Blue and Bendire were crossed on the regular stage route.

With the curtailing of the range and consequent driving of the open-range business into the more inaccessible and rocky areas, overstocking must inevitably follow. This condition has been reached in practically all the open ranges of the country, but more interest is attached to this condition in those regions where the grasses do not form a sod, as is the case with the one in question, because trampling and close grazing result in more speedy and permanent injury than in the sodded regions. To say that the southern portion of the region is overstocked would be putting the matter very mildly. The more northern portion over which we traveled was in better shape. The Bendire Mountain region especially had exceptionally good feed, and was, as a whole, the best range which we saw on the whole trip. Portions of the Blue Mountains were also in very good condition. In all the other highlands overstocking was very conspicuous. The White Horse Mountains were being pastured by sheep the second time this season. They were grazed earlier in the summer, and flocks were being driven into them again from the Disaster Peak country when we were there early in August. One herder reported that the latter place was all eaten out and that he moved his flock in order to avoid trouble with other herders who were quarreling and disputing over the little grass left. The first pasturing had left the range short enough; what the second will do can be easily imagined.

The most closely pastured region visited was Steins Mountains. On the whole trip of three days we found no good feed, except in very steep ravines, until we reached the vicinity of Teger Gorge. On a portion of the trip from here to Manns Lake there was a good stand

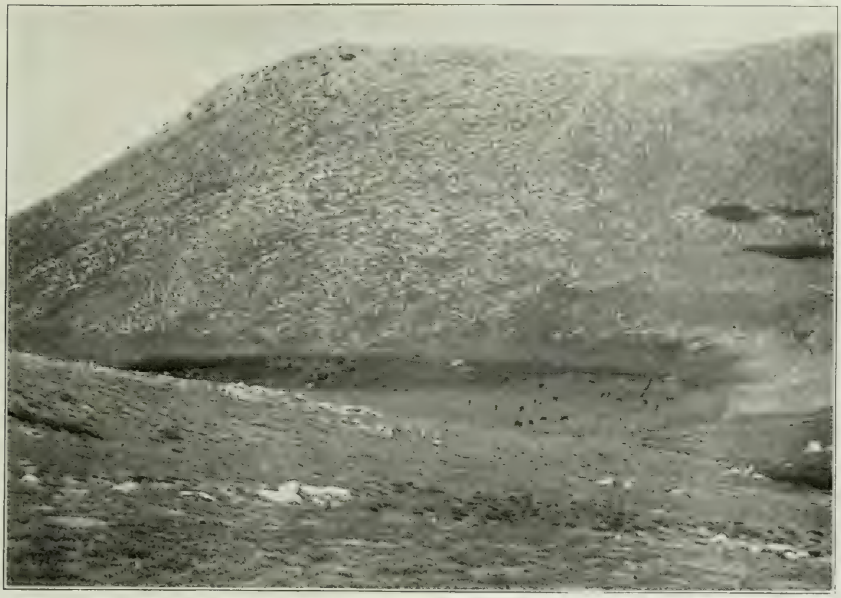

FIG. 1.—CATTLE RANGE IN PINE FOREST MOUNTAINS, NEVADA.

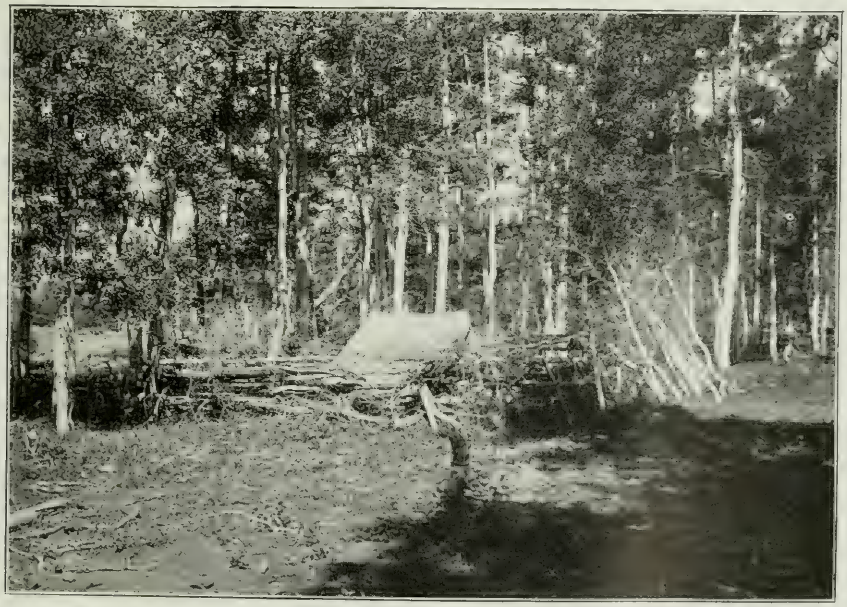

FIG. 2.—HERDER'S HABITATION DURING THE SUMMER GRAZING SEASON IN STEINS MOUNTAINS, OREGON.

of grass, the side of the gorge and the area immediately to the east being exceptionally fine. There were a good many cattle in the locality, but no sheep had been pastured there this season. In places from Ankle Camp to Nuttersville, a sheep supply camp, there was practically no more feed than on the floor of a corral. We passed two areas at least 2 miles in extent in which even the surface of the ground was reduced to an impalpable powder. Pl. IV, fig. 2, taken in the Pine Forest Mountains, shows the condition of the surface of the ground after close pasturing by sheep. This evil effect is most likely to occur in the sagebrush and other shrubby areas, mainly on account of the habits of the sheep. Pl. V, figs. 1 and 2, illustrates the point in question. During the morning the animals feed, spreading out over more territory and move about, while during the heat of the day they get as much shelter as possible, hanging their heads in the shade of the shrubbery, if such is available. If not, they bunch up together and use the shade furnished by the bodies of the other animals. They feed and move around but little; on the contrary, remain in nearly the same place, although they keep their feet in almost constant motion. This movement of their feet on the surface of the ground for hours at a time reduces it to a fine powder. The illustration, Pl. IV, fig. 2, is from a photograph taken with the camera pointing downward, and covers a space of about 28 by 40 inches. An analysis of this figure, which is typical of the effect of close sheep grazing in all of the shrubby areas, will show two species of plants upon the soil—one is a lupine on the extreme left, the other is sheep fescue (*Festuca ovina*), two bunches of which are shown, one on the extreme right and the other a little to the left of the upper central portion of the figure. The leaves of the lupine, a plant seldom eaten, are seen scattered over the surface of the ground. The other objects shown are sticks and pebbles.

The injury to the open grassy areas from overstocking results mainly from too close cropping, which exposes the bunches of roots to the direct rays of the sun, and deprives them of the beneficial action of the accumulation of débris from previous years, both in protection from excessive heat and in holding moisture. On this trip we crossed three areas of this grass, varying in extent from 3 to 60 acres, upon which the beautiful pure growths of sheep fescue were completely ruined. The bunches of great size were completely killed. Pl. IV, fig. 1, shows one of these localities. The objects in the foreground are mainly closely cropped bunches of this beautiful grass which under natural conditions stands at a height of from 1½ to 2 feet, and, although in bunches 4 to 10 inches apart, the abundant and graceful culms cover the entire surface. Under ruinous pasturing the bunches appear to die usually from the center. One may often find in these mountains a narrow green ring fringing a dead center. It is a very striking characteristic, and is found in many places. In the figure referred to above the grass is completely killed.

Sheep fescue produces an abundance of seed and is easily grown in the cooler regions of the United States, but whether it will reseed itself readily on the open range when thoroughly killed out over a certain area does not appear clear. As far as we know there are no definite observations on this point, but judging from the habits of the grass, the general appearance of the bunches, and observation of the denuded areas visited, the process will be exceedingly slow. One small ruined area visited had the appearance of having been used as a bedding-down place about two years ago, and evidently had not been pastured since. Here the old bunches of roots needed nothing more than a kick to remove them from the ground. There appeared to be no evidence that the area was being reseeded, nor that other permanent vegetation was taking the place of this one. It appears from these observations that the process of recuperation when once the grass is killed will be exceedingly slow.

Some statistics obtained from Mr. J. M. McKissik, who runs a camp in the mountains to supply the needs of the herders, show the enormous drain that is made upon these mountains for summer pasture. According to his statement a rough census was taken at the camp a few days previous to our arrival, in which it was ascertained that there were 73 flocks of sheep on the top of Steins Mountains at that time, each flock averaging about 2,500 animals. Conservative estimates of the area in which this pasturing was being done, furnished by the range riders and ranchers familiar with the region, give the length of the area as 50 miles by an average width of 8 miles, or 400 square miles. Accepting the rather low average of 2,500 animals to the flock, the figures indicate that there are 182,500 sheep, or over 450 animals to the square mile. According to Mr. McKissik's estimate of the area, there were over 1,000 sheep to the square mile. It is believed that the other estimate is more nearly accurate. The season of pasturage extends over fully four months, and at times from four and a half to five, depending upon the advent of the autumnal storms. Nor is this all. It must be remembered that there are cattle ranches located around the base of the mountains. Among these are ranches belonging to the French-Glenn estate and the Pacific Live Stock Company. These and about a half dozen smaller ranchers run their cattle into the same region as much as possible during the summer season. With these figures before us it is needless to say that feed was short, and that already in August some flocks were being driven onto what is known as winter pasture on the lower levels, which are not usually pastured until the middle of October.

The shrubbery plays a very important part in the forage supply of the mountains also. The extensive areas of cinquefoil (*Dasiphora fruitocosa*) and Indian currant (*Symphoricorpos oreophilus*) are invariably defoliated by the sheep. It was difficult to find a twig of the former large enough to make a good herbarium specimen. Really the only shrubs not eaten here appear to be mahogany (*Cercocarpus ledifolius*) and snowbush (*Ceanothus velutinus*). Willows are always trimmed up as far as the sheep can reach, and the poplar (*Populus tremuloides*) is not only browsed, but the young trees are often completely girdled. There are two other plants which might be classed with those not eaten by sheep, namely, the sages (*Artemisia tridentata*) and *A. arbuscula*, to which should be added the long-leaved sage (*A. cana*), which is abundant in some localities in Steins Mountains. Even the wild chokecherry (*Prunus emarginatus*) is often browsed. The poplar thickets are trimmed up, however, by both cattle and sheep. While the sheep actually eat leaves, twigs, and bark of the young trees, the cattle tramp through the groves a great deal, especially in fly time.

Being familiar with the destruction of the surface of the country in the deserts of southern Arizona as a result of the removal of the vegetation and the packing of the surface by the trampling of large herds of cattle, a constant effort was made to ascertain the effect of the same agencies here. The conditions in this region, however, with reference to soil characteristics, character and amount of precipitation, and configuration of the surface are very different from those of southern Arizona; and the effect of flood waters are consequently by no means identical in the two localities. A comparison of the rainfall of the two regions will show that the precipitation at Winnemucca, Nev., is less by about 4 inches per annum than at Tucson, Ariz. This, coupled with the fact that the summer showers are much less frequent as well as less violent in the former than the latter place, would lead one naturally to infer that the waters would be much less destructive. The real mollifying influence, however, is not to be found in either the character or the quantity of the precipitation, but in the soil of the mesa, where the destructive action is the most pronounced. It is the impervious soil that always washes badly. The surface of the mesa in northern Nevada and southeastern Oregon, as far as observed, never bakes nor otherwise becomes hard and impervious to water, as do those lying over the caliche hardpans of southern Arizona. Here the hard impervious soils are found on the bottoms in the basin-like depressions and sinks and along poorly drained river banks. It will be readily seen that the effect of erosion would be to build up and level rather than to cut gorges. It is not meant that there are not notable incidents of recent erosive action here, but an attempt is made to show that the conditions are not as favorable for it and that it is insignificant compared with the same phenomenon on the southern deserts.

Fire has a direct influence upon the condition of the feed. Burning is as destructive to the grass of the range as to the trees of the forest. Indeed, it had sometimes been thought in more extended observations on the prairies of the Dakotas that fire is really more injurious than close grazing. This region is too far removed from railroads to have the numerous conflagrations attributed to that source. It can be attributed to no other agency than that of criminal negligence. In traveling from Burns to Drewsey, via Silvies, we passed over areas where six separate fires had raged during the past two or three months. Two or three of these were in progress when we passed through. In every mountain range visited evidences of fire were found. Even the snowbush (*Ceanothus velutinus*) was burned off in places in the vicinity of Bartlett Peak and in the White Horse Mountains. There appeared to be good evidence that the one in the former area was willfully set for the purpose of facilitating the movements of bands of sheep from one pasture to another. This evidence was corroborated by at least six individuals. The site of an old fire in the White Horse Mountains, set by Indians about three years ago, was very interesting from both scientific and economic points of view. The shrubbery was of course all burned off and a little of it was growing again from the stumps. The grasses showed a very marked difference in the degree to which they succumbed to the effects of the fire. The fescues appeared to be all killed, while the Nevada blue grass was growing nicely. Buckley's blue grass withstood the fire better than the fescues, but not nearly so well as the other blue grass.

It is strange that more care should not be taken of the little shrubbery and timber that exists in the region. It is with the greatest difficulty that the ranchers from Winnemucca to Burns are able to get sufficient wood for posts and fires. On many ranches poplar and juniper is about the only available timber for fence posts, and these must be hauled from 30 to 50 miles. Where brush and wood are so scarce and mean so much when considered from either standpoint of immediate use or that of conservation of moisture and protection of soil, more care should certainly be exercised to prevent fires. As an example of negligence we might mention one which came under our direct observation while en route between Silvies and the Calamity settlement. On reaching the headwaters of the Calamity drainage we met two parties, one evidently campers, the other a round-up outfit. Farther down the valley we discovered a locality where some party had camped the previous night. They had built two fires, one of which was kindled at the base of a large pine, which, at the time we passed it at 9 o'clock in the morning, was burning vigorously up to a distance of 10 feet above the ground. It is true that the whole region had been burned off a short time before. There was consequently no danger of further destruction excepting to this one tree, but the same negligence would doubtless obtain under other circumstances. It is needless to say that the winter feed was completely destroyed, and that it will take both grass and timber many years to recover

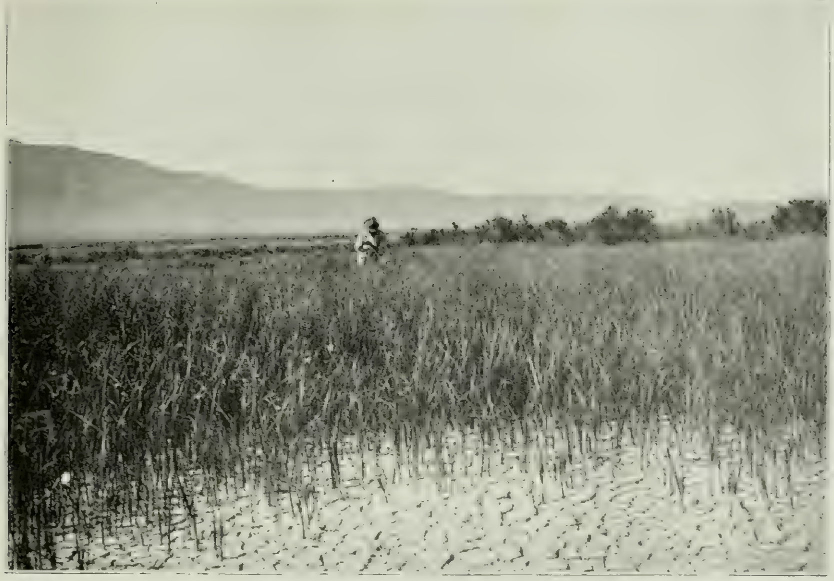

FIG. 1.—SHOWING THE HABITAT AND A FAIR CROP OF PRAIRIE BULRUSH ON MANNS LAKE RANCH, 20 MILES NORTHEAST OF ANDREWS, OREGON.

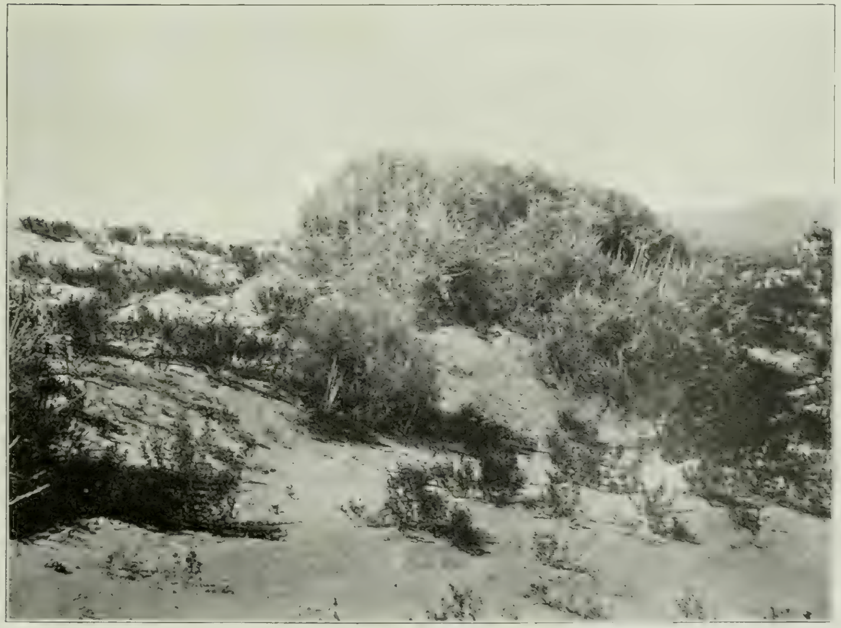

FIG. 2.—TETRADYMIA AND PSORALEA HOLDING DRIFTING SANDS, 20 MILES NORTH OF WINNEMUCCA, NEVADA.

from the effects of this one fire. It appears that much less vigilance is exercised in the control of fires in this region than in the pasture and forest lands of Montana and Wyoming, due, no doubt, to there being on the whole less combustible material, and consequently less probability of fire spreading, as well as to the fact that the country is more sparsely settled, and, therefore, the interests at stake are less carefully guarded.

HAY CROPS.

A general description of the lowland hay meadows has already been given. It remains simply to give a brief account of the principal hay crops, their quality and something relative to the methods of handling. Nothing is more evident than the fact that the yield is in direct proportion to the amount of care and the amount and distribution of water which the native meadows receive. The quantity of hay raised on the different ranches is enormous. Its quality, however, is rather low, for there is mixed with it oftentimes large quantities of wire grass (*Juncus balticus*), squirrel tail (*Hordeum jubatum*), tule (*Scirpus lacustris*), various species of sedges (*Carex* sp.), creeping spike rush (*Eleochris palustris*), and other plants having a smaller feeding value than the majority of the true grasses and clovers. Many sedges, however, produce hay of very fair quality.

The methods of irrigation of the native meadows are very primitive indeed. The waters during the flood season are held on the land as much as possible by the aid of low rough dams constructed of earth, brush, or refuse material. This plan floods the hay areas for periods varying from one to three or four weeks. After these spring floods pass by there is practically no more water for the native hay meadows until the advent of cold weather, when the lower areas again become flooded, and remain so, in some cases, until early summer. It will be readily recognized that this condition is not conducive to the development of the grasses, but furnishes, on the contrary, the exact environment suited to the growth of the poorer qualities of forage plants mentioned above.

In spite, however, of the natural disadvantages of poor drainage and heavy stocking, large and magnificent crops of hay are raised on some areas on all the ranches. The best hay, when both quality and quantity are considered, is probably furnished by the wild wheat or blue stem (*Elymus triticoides*), which furnishes oftentimes as high as 2½ tons to the acre. Especially fine meadows of this were seen on the Humboldt River bottoms at Winnemucca and in the Quinn River Valley at Quinn River Crossing. (See Pl. XIV, fig. 2.) The best quality of native hay is doubtless furnished by the bunch blue grass (*Poa lævigata*), which in favorable years and localities makes an excellent stand and furnishes from 1½ to 2 tons of hay per acre. Next in importance to these two grasses should be mentioned the native clovers, several species of which are to be found in the region, but the most important one is *Trifolium involucratum* in some of its various forms. Both the quality and quantity of the hay furnished by these plants are excellent. They grow very profusely in the low boggy sedgy meadows, and very naturally improve the quality of the native hay in these situations, which, were it not for these leguminous crops, would produce little aside from the sedges and rushes. Very often, as was the case on the Divine Ranch, these furnish one-half of the hay on these areas, the remainder being furnished by the sedges and rushes. Occasionally giant rye grass (*Elymus condensatus*) is cut for hay on the drier bottoms. It makes a coarse quality of forage, and its main use is winter pasturage. (See Pl. XIII, fig. 2.) The following list of forage plants from the meadows of Quinn River Crossing are representative and give a good idea of the character of the vegetation on these areas: Sedges (*Carex lanuginosa*, *C. douglasii*, and *C. nebraskensis*); salt grass (*Distichlis spicata*), red top (*Agrostis alba*), alkali saccaton (*Sporobolus airoides*), squirrel tail (*Hordeum jubatum*), wild barley (*Hordeum nodosum*), orchard barley (*Sitanion longifolium*), wild wheat (*Elymus triticoides*), giant rye grass (*Elymus condensatus*), slender wheat grass (*Agropyron tenerum*), bunch blue grass (*Poa lævigata*), steel grass (*Sporobolus depauperatus*), slough grass (*Beckmannia erucæformis*), beard grass (*Polypogon monspeliensis*), creeping spike-rush (*Eleocharis palustris*), rush (*Juncus balticus*), prairie bulrush (*Scirpus campestris*), tule (*Scirpus lacustris*), clover (*Trifolium involucratum*), seaside arrow grass (*Triglochin maritima*), cat-tail (*Typha latifolia*).

The native meadows of the Malheur Lake bottoms deserve special mention. The principal study of these was made on the Island Ranch between the forks of Silvies River. The quantity of water with which these areas are flooded is enormous and remains upon the ground for a long period. Consequently, the sedges and rushes develop to an astonishing extent. There are here grasses also which make an excellent growth. (See Pl. XV, figs. 1 and 2.) The one characteristic above all others which impresses one is the exceedingly patchy character of the vegetation on the low, level, poorly drained bottoms. The most valuable forage plants appear to be the wild wheat or blue stem (*Elymus triticoides*), prairie bulrush (*Scirpus campestris*), sprangle top (*Scolochloa festucacea*), awned sedge (*Carex aristata*), and yellow top (*Calamagrostis hyperbora americana*). These forage plants, together with the less valuable tule (*Scirpus lacustris*), rush (*Juncus balticus*), cat-tail (*Typha latifolia*), creeping club rush (*Eleocharis paulstris*), and bur-reed (*Sparganum eurycarpum*), are scattered around over the bottoms in areas of variable extent, but usually in patches of but few

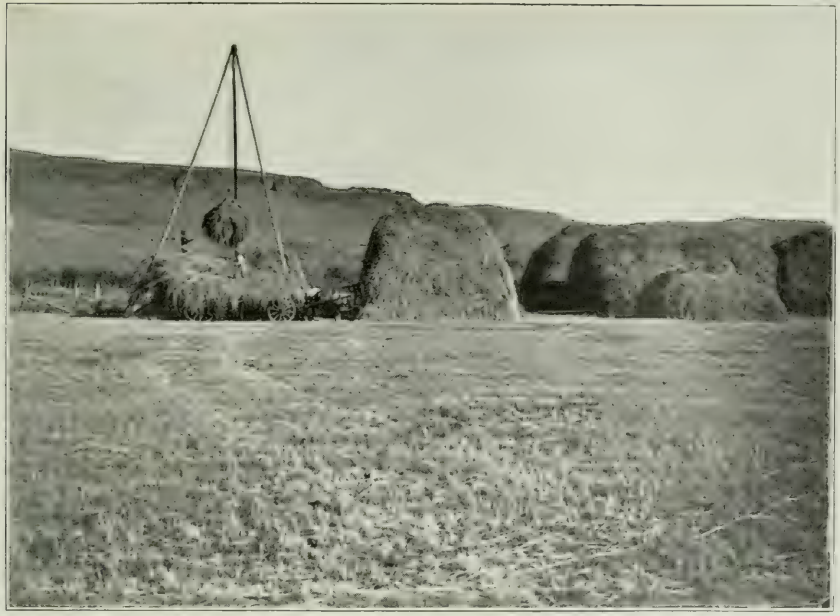

FIG. 1.—STACKING HAY WITH A JACKSON FORK AND TRIPOD, THOMPSON BROTHERS' RANCH, NEAR BEULAH, OREGON.

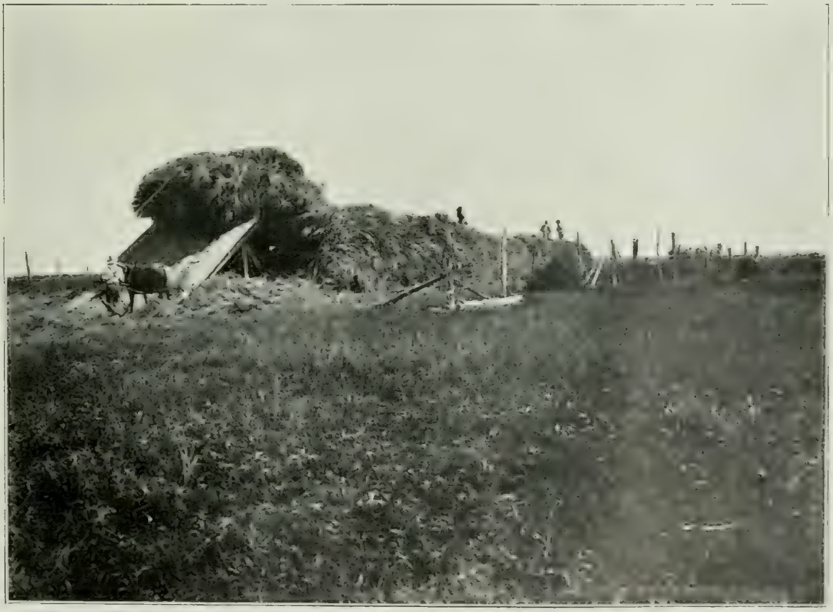

FIG. 2.—STACKING HAY WITH A "SLIDE," ISLAND RANCH, MALHEUR LAKE BOTTOMS, OREGON.

A ton of hay is on the slide.

rods in diameter, or, as is usually the case with the yellow top, in narrow fringes along the lower areas. Large quantities of hay consisting of almost pure sprangle top and prairie bulrush were being harvested on the ranch when we were there.

The cultivated forage plants are few in number. As in all the arid West where irrigation is practiced, alfalfa is found to be by far the most profitable crop, and it seems especially well adapted to the only tillable soils of the region, namely, the lower sagebrush areas. Whenever water is available for irrigation the sagebrush lands invariably raise good crops of this important forage plant. It is in the northern portion of the region covered that it is raised most extensively and profitably. One field near Ontario, Oreg., was pointed out to us as having raised last year 10 tons per acre in three cuttings. It was an unusually fine field, and care had been taken to get a good even stand. (See Pl. XIV, fig. 1.) Judging from the comparative appearance of other fields in the vicinity, 6 tons per acre would be a fair average for the region. Farther south, where water is less abundant and only two cuttings are made, 3 or 4 tons would be a good average. Here considerable growth occurs in the fall after the second cutting is made, but this is usually pastured off by cattle which are turned into the fields during the winter. In this way the alfalfa fields, as well as the native hay meadows, furnish both hay and winter pasture.

Redtop (*Agrostis alba*) is widely introduced in the basins of Nevada and Oregon and often furnishes large quantities of hay and pasture on the low, moist bottoms. It is of more importance from the Alvord Desert region north than it is farther south. The first place where we saw a good stand of it was on the Divine ranch.

Timothy is being more widely introduced in recent years and is said to withstand the alkalinity of the soil better than any other forage plant known to the ranchers of the region. Instances were cited to us of successful stands having been obtained on soil which produced nothing but greasewood. In some places on the Divine ranch there were fine crops of it. In one field the hay consisted of about equal quantities of timothy, redtop, and native clover, a most excellent combination for a good quality of hay. Mr. Divine reported that the clover had "come in" of its own accord, and that the redtop in this particular field was the result of having fed redtop hay which was hauled in from a small ranch established in early days farther down the valley.

METHODS OF HANDLING HAY.

The methods of handling hay crops are certainly unique and in thorough keeping with the extensiveness of all the operations connected with stock raising in the region. The many appliances used permit of handling the crop to the best advantage and with the least possible expense. On the majority of the ranches practically all of the work is done by machinery. There are some, however, who purposely sacrifice speed and manual effort in the handling of alfalfa, especially, to enable them to gather the crop with less loss than by the use of machinery, but more will be said regarding this feature later.

In harvesting a crop of hay a crew of from sixteen to thirty men is employed to attend to the various operations of mowing, stacking, bucking, net tending, hoisting, sickle grinding, and blacksmithing during the entire haying season, which lasts from two to three months. Pls. VIII, figs. 1 and 2, IX, figs. 1 and 2, and X, fig. 2, show some of the machinery used in stacking or piling up the hay, as the process is often very appropriately called, in actual operation on the ranches in eastern Oregon. Probably the most rapid method of any in vogue is that known as the "slide" method, which is employed only on the largest ranches where native hay is the predominating crop. A "slide" consists essentially of a huge, strongly built inclined plane. The hay is brought up to the base of the plane, usually by a four-horse buck, and deposited in a net, to which is fastened a cable stretched over the top of the plane and the entire stack. The other end of the cable is attached to the fore truck of a wagon, to which is hitched a four-horse team. When the load has been drawn up and discharged in the proper place on the stack, the net is drawn back to the base of the plane again by a single horse, readjusted, and reloaded. The four-horse buckload will average about one ton of hay, and a load will be run onto the stack once in six to eight minutes when the machinery is in good working order. Pl. VIII, fig. 1, shows the process of stacking by the use of this machine in actual operation on the Island Ranch, near Burns, Oreg. Another method more extensively employed than the "slide" is represented in Pl. IX, fig. 1. This is very similar to the former, differing from it only in the substitution of a derrick for the slide. The bucks and net are used in both cases, but their capacity is usually smaller than those operated by four horses instead of two. Where the ground is very rough a drag buck is substituted for the wheeled one in ordinary use. Pl. X, fig. 2, illustrates one of the large four-horse bucks—the smaller ones differ but little except in size.

Both of these processes are best adapted to the handling of native hay, which is not much injured by rough treatment. The bucks are especially hard on alfalfa, one of the most difficult hay crops to cure and handle properly. With rough treatment, such as it is certain to receive when bucked to the stack, the friable leaves, the most valuable part of the plant, are almost certain to be largely broken off. To obviate this very decided objection many of the ranchers discard the bucks entirely in handling the alfalfa crop and haul the hay to the stack in wagons. It is then unloaded by means of a derrick or tripod arrangement and a Jackson fork, as shown in Pls. VIII, fig. 1, and IX, fig. 2.

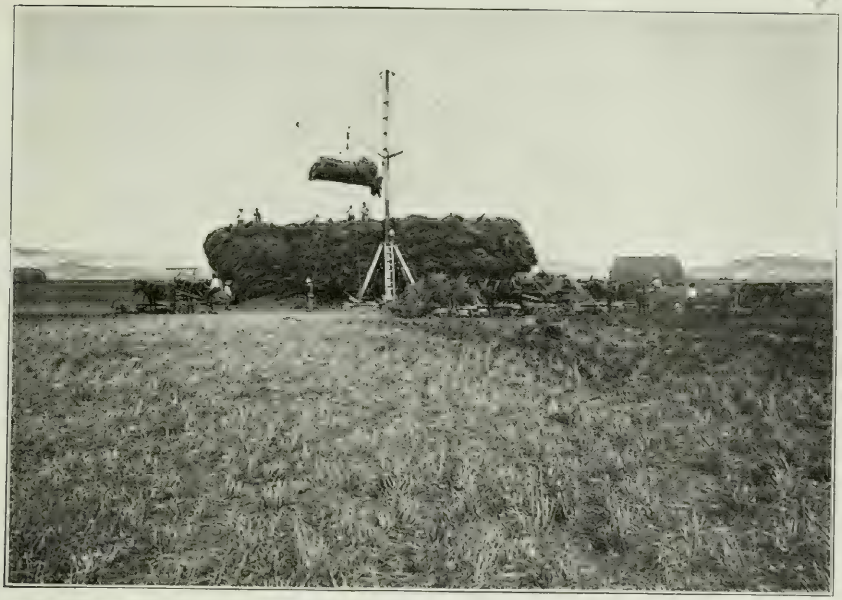

FIG. 1.—STACKING ALFALFA WITH A DERRICK, HARPER RANCH, NEAR WESTFALL, OREGON.

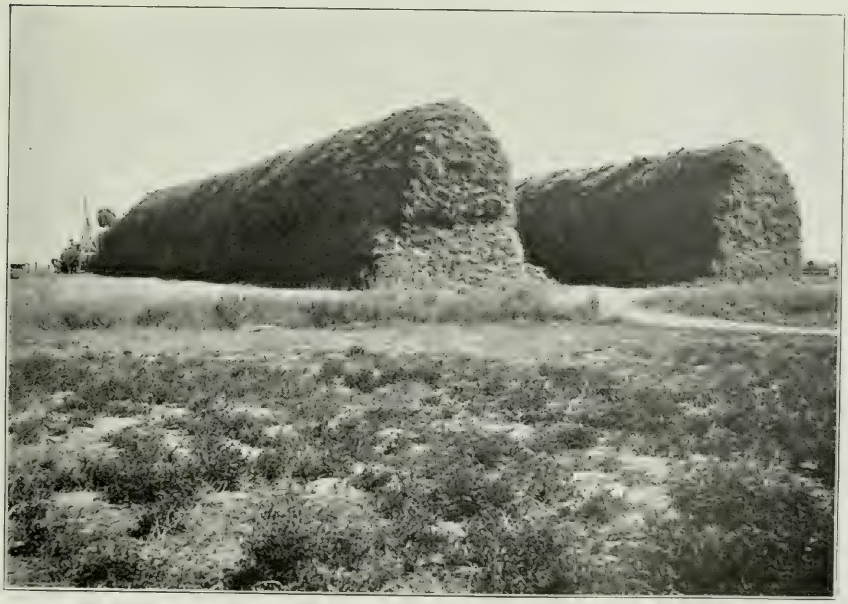

FIG. 2.—STACKING ALFALFA WITH JACKSON FORK, ARCADIA RANCH, NEAR ONTARIO, OREGON.

Stacks are 375 feet long, 75 feet over, and 28 feet across

In this way the leaves are saved and the most difficult part of the manual labor, the transfer of the hay from the load to the stack, is still accomplished by the use of machinery. Another very decided disadvantage of the "slide" method results from the difficulty of making the stacks waterproof. Of course this can be accomplished, but when a ton of hay is dropped in one place on the stack and similar quantities are put up at such short intervals, the stackers do not usually work it over so as to make the mass of uniform density. The consequence is that there are places in the stack that are not well packed. When the hay settles "holes" occur, allowing the rain water to drain into the stack. This would not be of so much importance if all of the crop were fed the year it is cut, but this is often not the case. Much hay is sometimes held over to be fed the subsequent year. It is needless to say that if not properly stacked it deteriorates very much in value. Some of the last year's stacks of native hay put up by this method which we examined were at least one-half rotten or moldy, while alfalfa stacks carefully put up by the derrick method had deteriorated but little, although native hay can be made to shed water much easier than alfalfa.

All of the hay raised is for home consumption and, in practically all cases, is fed in the same fields where harvested. This is due not only to the good price of beef, mutton, and wool, but also to the prohibitive transportation tariffs and long distances from market.

SAND BINDERS.

All plants growing on sandy lands which are shifted by winds act as sand binders and prevent, to a greater or less extent, the movement of the sands. If a plant grows on such areas, therefore, it is to some degree a soil or sand binder, and whether valuable as forage or not, it serves a useful purpose in preserving the surface of the land intact until it shall have become stable enough to support other and less persistent vegetation. The appellation, sand binder, is therefore one of degree rather than of kind, although usually applied to those plants which have a means of efficient propagation enabling them to develop rapidly and furnish a protective soil cover in regions where the configuration of the surface is easily disturbed. The two first named plants may be classed as true sand binders. The others perform some service in this respect, but they have no special means of propagation which enables them to draw upon the moisture and fertility of the deep-lying strata and at the same time extend the area over which they grow rapidly during dry weather.

PSORALEA (*Psoralea purshii*).—This plant, although it does not grow on soils which change their positions as rapidly as the next, is still, on account of its abundance in very sandy soil and under very adverse conditions, the most important soil binder of the region. Many large areas are to be found in northern Nevada, especially in the vicinity of Winnemucca and on the narrow strips of sandy land which are usually found in the vicinity of the basin-shaped depressions described elsewhere, which have very little vegetation aside from this plant.

DELEA (*Delea kingii*).—On the sand hills about 20 miles north of Winnemucca, this is the only plant which is able to sustain itself in rapidly shifting sands. It usually grows sparingly but evenly over large areas, propagating rapidly by its long slender reddish rootstocks, which may be easily pulled up out of the loose sand through which they ramify. The spinescent branches, the yellowish-green coloration of the leaves, the reddish rootstocks, and the purple flowers give this plant a very characteristic and striking appearance as it spreads over freshly formed hillocks and mounds of sand.

TETRADYMIA (*Tetradymia comosa*).—Large bushes of this were found in abundance in the same vicinity as *Dalea kingii.* Almost invariably they were situated upon mounds or half buried in the sand, indicating that the soil had been removed from the surrounding areas or had been piled on top of the plants. Pl. VII, fig. 2, illustrates the effectiveness of this plant in preventing the sands from drifting.

MOSS (*Tortula ruralis?*).[a]—It is with considerable hesitancy that a moss is recorded as a sand binder, but that this species serves this useful purpose over quite extensive areas in northern Nevada and eastern Oregon is perfectly apparent to anyone visiting the region between June and October. This small plant does not grow over the entire mesa, but, on the contrary, is confined to circumscribed areas immediately beneath and immediately surrounding shrubby plants, such as black sage, spiny saltbush, tetradymia, and the shad scale. Its period of growth is evidently late winter and early spring, at which time it forms a complete covering for the ground. When conditions of drought appear it dries up completely, and, while easily removed from its position, it forms mats which catch the sand that blows into it, and serves in this way to enlarge the small mounds which appear surrounding the desert shrubbery. Every area of this plant examined was almost completely imbedded in sand. That it grows in this way is not at all likely, because an abundance of leaves were always found below the surface of the sand, indicating that the plant had been covered after the advent of dry weather in late spring and early summer.

Besides the plants mentioned above, many others might be named in this connection. The sandy area on the south and east of the Alvord Desert in southern Oregon showed a very marked influence of some of the common desert shrubs upon shifting sands. Among plants which acted as sand binders in this locality and were almost invariably found in hillocks of sand may be mentioned the spiny saltbush, shad scale, and the black sage.

WEEDS.

It will be noticed that this short account gives special prominence to native plants which occur to such an extent as to be classed weeds. This is not at all to be wondered at in a region so little improved as the one in question, and, in a region where the preponderance of the crops on both pasture and hay lands are harvested on the untilled ground, and consist of native plants which receive no other care than that of harvesting. Under conditions where the pasture and hay lands are taxed to their full capacity, the fact that some plants which are not relished by cattle increase to an unsightly or even alarming

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[a] Determined by Mrs. E. G. Britton.

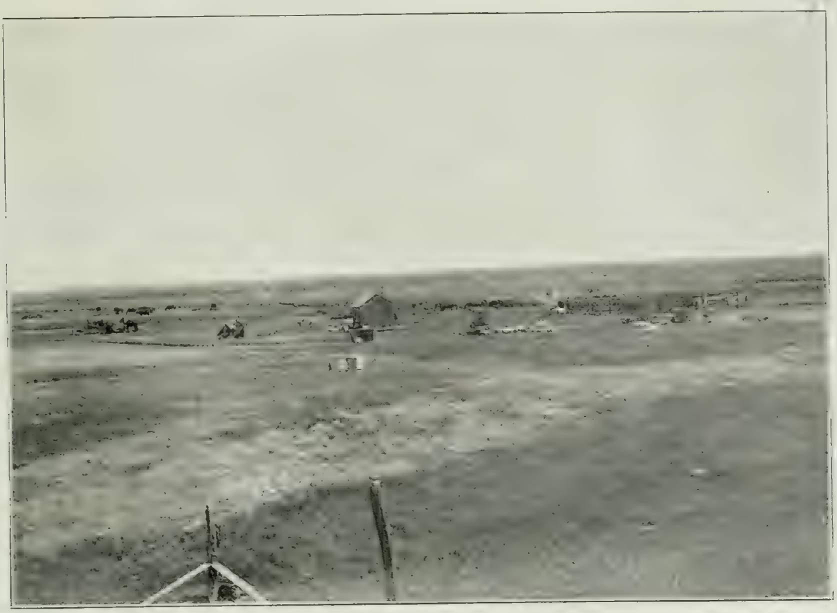

FIG. 1.—A HAY CAMP, ISLAND RANCH, MALHEUR LAKE BOTTOMS, OREGON.

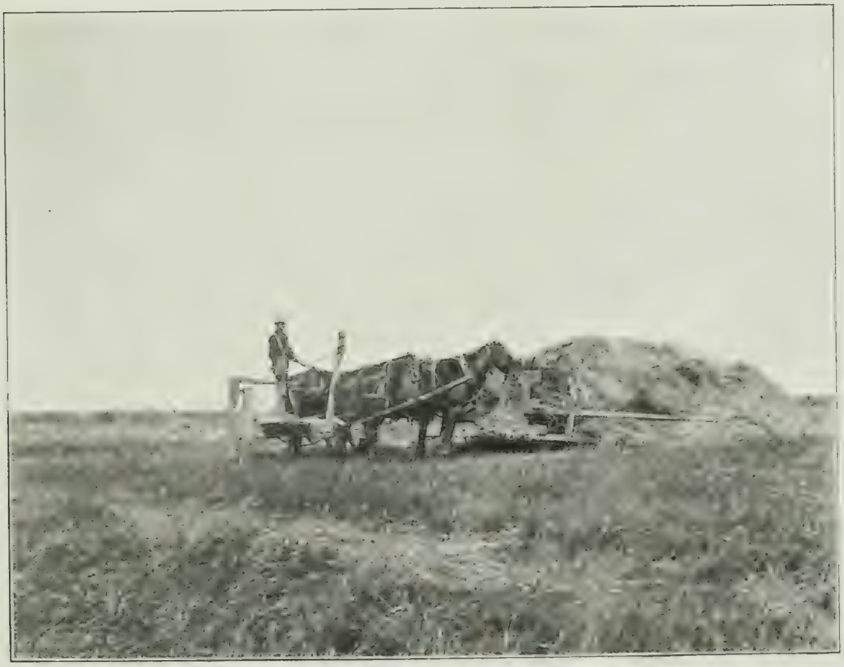

FIG. 2.—LOADED FOUR-HORSE BUCK, MALHEUR LAKE BOTTOMS, OREGON.

extent is not at all surprising. No attempt is made to give a complete weed list for the region, but, on the contrary, only those are enumerated which interfere with the growth of forage crops. Even some of these are valuable forage plants in themselves, but they are listed here because of their persistency or their frequent occurrence in ground sown to other forage crops or in localities which, were it not for their presence, would yield more valuable feed.

The number of plants recorded in this connection might be greatly extended by accepting a more liberal interpretation of the meaning of weed and by an enumeration of the less harmful ones. Such plants as wire grass (*Juncus balticus*), which produces a very poor quality of hay, mint (*Mentha canadensis*), and heliotrope (*Heliotropium curassavicum*) grow in great profusion, but they develop only in places and under circumstances where nothing else will grow. They therefore serve the useful purpose of furnishing a soil cover after the flood water disappears, and some of them even furnish a poor quality of feed. The plants which interfere in native meadows are few compared with those which are troublesome in alfalfa meadows. Here under the stimulus of too superficial cultivation they receive a great impetus, and, under unfavorable conditions for the development of the cultivated crop they interfere with its growth and very materially reduce the value of the hay and the pasture.

DEATH WEED (*Iva axillaris*).—This is undoubtedly one of the most persistent weeds in northern Nevada and southern Oregon. It grows very profusely in low alkaline meadows and pastures. In many places where pasturing has been carried to excess it forms a complete covering for the ground, and often, as was the case on large areas in the Quinn River Valley, no other plants grew with it. It is also at times a very bad weed in cultivated lands, and in such cases interferes very materially with the crop. Its habit of propagation by creeping rootstocks renders it a very difficult plant to eradicate. With thorough cultivation, however, no serious apprehension need be had concerning it, as in ground thoroughly plowed and cultivated each year it soon disappears. It gives the greatest amount of trouble in land which is only partially subdued, such as the lower sage-brush areas. In this region of scanty rainfall, where alfalfa is about the only cultivated crop raised, and where it is by far the best paying crop, the rancher is liable not to thoroughly prepare the ground for its reception. Very often a sage-brush area is cleared up and sown to alfalfa with no other crop preceding it. In such cases, as will readily be seen, the ground is not thoroughly prepared, and this weed as well as many others will persist in the soil to the detriment of the crop for several years.

SUNFLOWER (*Helianthus annuus*).—This widely distributed weed frequently interferes very materially with the development of the forage crops, especially in the newly broken bottom lands or rebroken pastures and meadows. Its development was especially abundant on the ranch of J. S. Divine, also in certain localities on the Malheur Lake bottoms. On Mr. Divine's ranch it, together with the horsetail spoken of below, formed about one-third of the crop of grain hay.

HORSETAIL (*Equisetum robustum*).—This is often pointed out as a vile weed, but it seldom does much damage where land is properly treated. In localities where it was noticed this year the land had been overirrigated and poorly cultivated.

BLUE FLAG (*Iris missouriensis*).—Large areas of this are found in the mountain meadows and especially in depressions and "draws," which furnish large quantities of feed, consisting of native clovers and sedges. It seems never to be eaten by either cattle or sheep, and forms a very conspicuous weed in the localities mentioned.

MUSTARD (*Sophia pinnata*).—In southern Oregon this appeared to be the worst weed in alfalfa meadows. At Denio the alfalfa hay with which our horses were fed at the livery stable consisted of at least one-half of this plant. While this was the worst case seen, it was very commonly found in large quantities in the alfalfa hay throughout the region. To the north and south of this place, however, less of it was observed.

LETTUCE (*Lactuca scariola*).—This was not prominent enough to attract any attention until we reached the headwaters of the Malheur River. From here on to Ontario it steadily increased in quantity. It was especially abundant in alfalfa meadows in the lower course of the Malheur River. Several fields were seen in the vicinity of Vail, in which this plant grew about as thick as it could well stand and as high as one's head.

WILD OATS (*Avena fatua*).—This, like the previous species, attracted no attention until we reached the headwaters of the Malheur River. It was common, however, all along the trip, but not of so much consequence in this region as where small grains are grown. There may be large quantities of it in alfalfa fields, but it is usually cut at such a time as to make very good feed, and thus every cutting tends to clear the land of it. In as much as alfalfa is cut often the oat does not have time to mature its seed.

SQUIRREL TAIL (*Hordeum jubatum*).—This is probably the most persistent and troublesome weed which inhabits native meadows. When it occurs, as is often the case, in hay land, the quality of the feed is very decidedly reduced by its presence. In this condition it is not relished by stock, and when forced to eat it they often become emaciated and their mouths become sore on account of the accumulation of the beards between the teeth. However, as stated elsewhere, it is not wholly a weed, for it often forms, with proper management, a very palatable and nutritious pasture or hay ration.

BARNYARD-GRASS (*Panicum crus-galli*).—In but one locality was this found in any quantity which attracted attention. Here there was a phenomenal growth of it. On the Harper ranch, on the Malheur River about 40 miles above Ontario, a large field of alfalfa, seeded last spring, contained a remarkable volunteer crop of this grass mixed with it. It was very noticeable, however, that it developed in the lower portions of the meadow in which the water from the two irrigations applied accumulated and remained for sometime before soaking into the ground. In this area, particularly, there was a growth of at least two tons of hay per acre. As would be expected, the alfalfa was completely killed out, due, in all probability, not to the presence of the weed, but to overirrigation and improper drainage. (See Pl. XVI, fig. 1.)

UTAH SALTBUSH (*Atriplex truncata*).—This, like the two following species, often grows in great quantities in low, poorly drained, alkaline, alfalfa meadows. It was especially abundant in such localities near Beulah, on the north fork of the Malheur River.

HALBERT-LEAVED SALTBUSH (*Atriplex hastata*).—Much of this species is often cut with alfalfa and also with native forage plants. It is questionable whether it ever interferes very materially in alfalfa meadows, although large patches of it frequently occur. It usually develops in situations which are either too alkaline or too poorly drained for the former.

PAHUTE WEED (*Dondia depressa erecta*).—This plant, which is said to receive its name from the fact that the Pahute Indians used the seed for food, is a weed in the same sense as are the two previous ones, and the notes under those species apply equally well here.

White sweet clover (*Melilotus alba*).—This weed, so common in nearly all irrigated regions, is very abundant northward. It does not appear to find congenial conditions in the southern portion of the Territory, but is especially unsightly along irrigation ditches in the drainage of the Malheur River.

POISONOUS PLANTS.

There is in this region as in all other grazing areas a very vague and indefinite idea regarding this class of plants. One will often find valuable forage plants pointed out as injurious to stock and passing under the vague term of "loco weeds." The prejudice against a certain plant often arises from some circumstance connected with the behavior of cattle in the vicinities where it grows in abundance. Cattle die for an unknown reason and the most natural thing to attribute the malady to is the poisonous effect of some plant. It has appeared, on this trip as well as on others in range States, that there is much popular misconception in reference to the matter. Usually it is difficult to obtain definite information concerning authentic cases of injury to stock from eating the plants in question. When one takes cognizance of the numerous species which are considered poisonous and then follows up the sheep camps or studies closely pastured meadows for a few days, he is sure to lose confidence in much of the popular belief concerning the poisonous effect of plants. There are two species, however, in this region which are universally condemned, and there is strong evidence that they do much injury at certain seasons of the year. As far as we were able to learn there was no injury from either except in the early spring.

Larkspur (*Delphinum scopulorum*).—According to the account given by Mr. F. C. Lusk, superintendent of the French-Glenn estate, this plant is one of the first to put forth a vigorous growth in the spring. When the ground is still moist, the cattle pull up the tuberous roots and eat them along with the succulent tops. He reports that there are no prominent symptoms following the feeding on this plant, and that the cattle simply "lay down and die." This account has been repeated substantially by other observers in the region, so that it appears to be well authenticated. While the plant appeared to be common enough in the mountains where we traveled, it was only in two or three localities that it was conspicuous. It is said to be more noticeable in the spring on account of its early appearance when there is less vegetation on the ground. The stock at this time of the year, after having been confined to dry, dead, and very short pasture grasses of the lowland meadows during the winter, are, of course, very eager for green feed and consequently eat many things which they would not touch later in the season when feed becomes more plentiful.

Attention is called here to the fact that injury from this plant, as well as the next one mentioned, occurs when cattle are first turned onto the range from short pastures or short hay rations during a long and often hard winter. They often go out in spring in a condition of very low vitality. It is suggested that the large death rate at this season may to a large extent be due to the radical change of ration at a time when the general tone of the system, owing to impoverishment and change of season, is least able to withstand such changes. The fact that at times cattle die in large numbers at this season of the year, when the system is least able to withstand the effect of noxious weeds or other injurious agencies, would tend strongly to create a suspicion that the condition of the animals acts as a very potent factor in causing the numerous losses.

WILD PARSNIP.—At least two plants designated by this common name are universally condemned. They are both very common in the lowland meadows and pastures in both northern Nevada and southeastern Oregon. These are known to botanists as *Sium cicutifolium* and *Cicuta vagans*. Large quantities were cut with hay at Winnemucca and Quinn River Crossing, Nev., and on the White Horse Ranch, near old Fort Smith, Oreg. No complaints are expressed against them in this condition. Like the larkspur, they appear to be injurious in the spring when the ground is moist and the cattle are able to pull up and eat the roots. In this instance again the injury occurs at the time when the cattle are in an impoverished condition and therefore least able to withstand the effects of any deleterious agents. Mr. Lusk reports that his company has paid out considerable money in attempting to eradicate this weed. It hires Indians or other cheap labor to dig up the plants in much the same way that the dandelion and the thistle are removed from lawns in the East.

FORAGE PLANTS.

No attempt is made to give a complete list of the forage plants of the region, even so far as observed on the trip. This would evidently include all of the grasses, sedges, and rushes, and would unduly extend the appended list to no purpose. Indeed, many of the plants collected which are known to be eaten by stock are purposely omitted from the list, either because they grow in quantities too small to be taken into account, or because they are not considered of sufficient importance to be noted.

THE TRUE SAGES.

The sages as popularly recognized constitute a very heterogeneous group of plants. A rough classification is frequently made, however, by the rancher into black sage and salt sage. The group included under the above head constitutes those shrubby plants belonging to the genus *Artemisia*, which bloom late in autumn and produce very inconspicuous flowers and seeds which are very seldom seen by the ordinary observer. They differ from the next group—the salt sages—in having a very bitter taste and a very penetrating odor, like the common wormwood to which they are closely related. They grow in those situations which although arid are seldom alkaline. The abode of the conspicuous and most valuable ones is therefore above the basins and river bottoms, on the mesas and in the foothills. The different species differ greatly in their forage value, depending presumably upon the quantity of the bitter principle present in the leaves and twigs.

BLACK SAGE (*Artemisia arbuscula*).—This sagebrush is the typical mountain form and differs mainly from the common black sage of the mesas (*A. tridentata*) in having larger flowers and more spreading scraggly branches. What is said concerning the feeding value of *A. tridentata* will apply with equal force to this species. Another species, which is closely related to the above and which is very common on the mesas

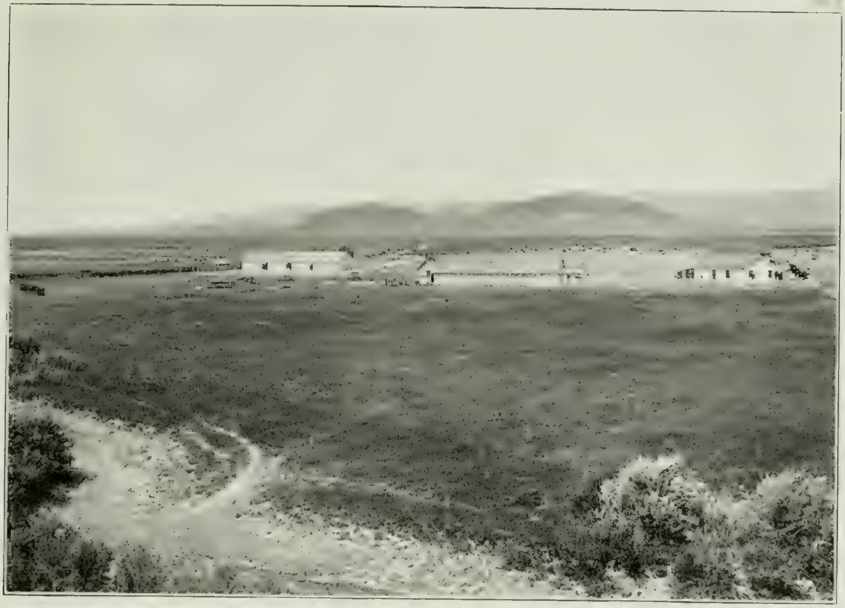

FIG. 1.—A TYPICAL NORTHERN NEVADA RANCH, QUINN RIVER CROSSING.

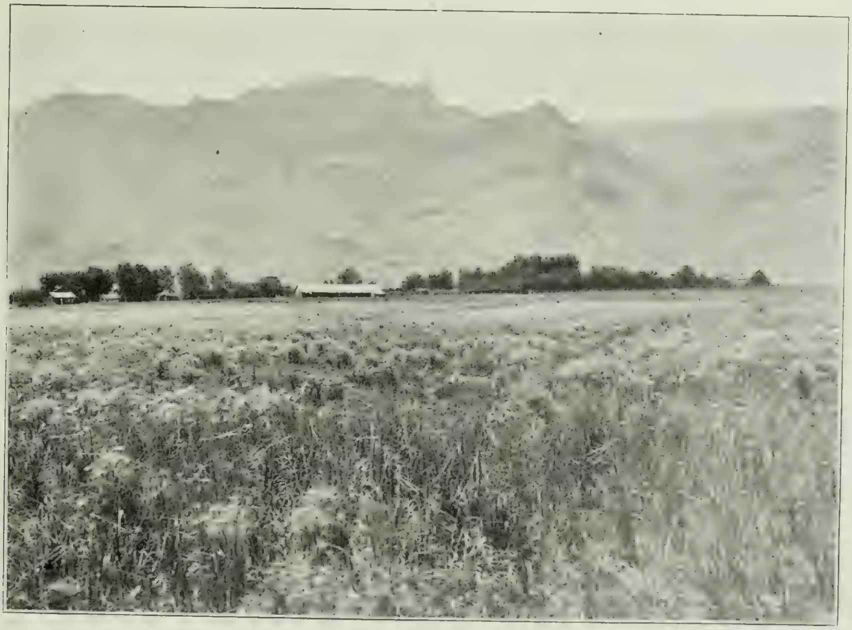

FIG. 2.—DIVINE'S RANCH, EASTERN BASE OF STEINS MOUNTAINS, OREGON

of the western Dakotas, portions of Wyoming, Montana, and Colorado, was found in one locality in Steins Mountains, where it covered quite extensive areas. This species, known to botanists as *A. cana*, differs from the preceding in having a more erect habit of growth and longer entire leaves. Its feeding qualities differ in no wise from those of the next species. (See Pl. VI, fig. 1.)

BLACK SAGE (*Artemisia tridentata*).—This is the common sage of the mesas and foothills. It takes the place of the Cactaceæ and the creosote bush (*Larrea mexicana*) of the deserts to the southward. Its feeding qualities are very inferior. It is sometimes said to be used for feed to a considerable extent, but its value is probably overestimated. According to the best information we are able to obtain, it is seldom browsed, even by sheep, excepting in extreme cases, and then it is claimed by the sheepmen of the region that the animals can not live upon it for more than a couple of days at a time. (See Pl. II, fig. 2.)

BLACK SAGE (*Artemisia rigida*).—This was met with in but two situations, the first near the Calamity settlement and the next near Westfall, Oreg. In both instances it was cropped very closely and it was with the greatest difficulty that we were able to secure specimens enough to identify the plant, inasmuch as we were unfamiliar with it, having never seen it growing before. Pl. III, fig. 2, shows this plant as it appeared near Westfall. The bunches in the foreground constitute what remains of the plant after being fed off during the winter months. In the background, both in front of and behind the wagon, will be seen a typical growth of the common black sage (*A. tridentata*).

MUGWORT (*Artemisia ludoviciana*).—A very common species of sage growing in general in higher nonalkaline lowland meadows. It is said to be pastured to a large extent in the winter, and very much of it is cut with other forage plants for hay. In this way it forms quite an important factor in the winter rations. It is probably relished much more by sheep than by cattle.

BUD SAGE (*Artemisia spinescens*).—A spiny, straggly shrub which blooms early in the spring and drops its seeds and leaves in midsummer, becoming almost, if not quite, naked by the middle of August. Of all the species of true sages that grow in the region this is undoubtedly the most important. It is said to be browsed by cattle as well as by sheep. As we saw it between Winnemucca, Nev., and the Alvord desert in Oregon, where it was exceedingly abundant on the foothills and high mesas, it invariably bore evidences of having been browsed during the past season. It is to be understood, of course, that this as well as the other species of the true sages are not eaten during the summer.

THE SALT SAGES AND THEIR ALLIES.

This group of usually salt-loving plants is of great economic importance in all the plains and basin region. Some of them form the main winter feed in many situations, while others, like the true sages, may be considered plants which form a subsistence ration. They vary greatly in the character of soil upon which they thrive, some, such as the common greasewood, being seldom found except on soils which are too alkaline for almost all other kinds of vegetation, while others, such as white sage and the spiny salt bush, probably never grow on what may be termed alkaline soil. All these plants belong to the goosefoot family, although they differ widely in their general appearance. They may be readily distinguished from the true sages by their more prominent fruits, winged seeds (fruiting bracts), and salty rather than bitter taste. Some species are annuals, but the majority of those which are most valued as forage are shrubby perennials.

SILVERY SALT BUSH (*Atriplex argentea*).—A bushy, branched, triangular leaved annual which develops in unsodded areas in native meadows and often in poorly cultivated fields on the lower elevations. In the latter situation it receives a stimulus from artificial cultivation and often makes a good stand. Much of it is cut with hay and is readily eaten by both sheep and cattle.

SHAD SCALE (*Atriplex canescens*).—A bushy, branching shrub, 3 to 10 feet high. It is most abundant in northern Nevada, where it grows commonly in the sandy stretches bordering low areas. It is less abundant and therefore of less consequence in this region than the next species mentioned, but it is probably relished more by stock.

SPINY SALT BUSH (*Atriplex confertifolia*).—A diffusely branched spiny shrub, 1 to 3 feet high, growing in nonalkaline situations on the mesas and foothills. Its habits are about the same as the bud sage, with which it often forms the only vegetation on large areas of the lower foothills between the draws where the black sage predominates. It is undoubtedly one of the most important winter feeds for sheep in the entire region, since the white and red sages have become so much reduced by overstocking.

HALBERT-LEAVED SALT BUSH (*Atriplex hastata*).—This is a branched, erect annual, growing in rather alkaline situations and having about the same value and habit as *A. truncata* and *A. argentea*. Like these two species, it sometimes develops tremendously in cultivated fields, in spots where the soil is too salty for the development of alfalfa and other cultivated crops. It often forms an almost pure crop in local areas in native meadows. In either case it is often gathered with the hay in considerable quantities and eaten by stock in winter. On the range it and the two species mentioned above are pastured to a large extent. These three species were especially abundant on the north fork of the Malheur River above Beulah, Oreg., and were common in hay meadows all the way from Winnemucca north.

NUTTALL'S SALT BUSH (*Atriplex nuttallii*).—A low spreading, sparingly branched shrub. This species was not seen until we reached the Malheur Lake basin, where it was found over large areas. It was again encountered in great abundance in the valley of the Malheur River, about 40 miles above Ontario. Wherever it was found it was invariably closely grazed on the open range. Pl. III, fig. 1, shows an area of this plant on the open range near the Harper ranch. All of the vegetation in the foreground, excepting the bunch of cactus, consists of stumps of this shrub. On the Harper Ranch there was one field which contained large areas which were protected during the summer. These areas invariably contained nothing but this season's growth of a few branches 6 to 12 inches long, showing how greedily the plant is eaten by cattle during the winter.

TORREY'S SALTBUSH (*Atriplex torreyi*).—A tall, diffusely, and rigidly branched shrub, 4 to 8 feet high, with triangular leaves, angular branches, and long, tapering spines. It was met with only in a few localities in northern Nevada, as far north as Quinn River Crossing. In the vicinity of Winnemucca it was browsed to about the same extent as the shad scale.

UTAH SALTBUSH (*Atriplex truncata*).—An erect, sparingly-branched annual, resembling silvery saltbush in general appearance and habit. Like the halbert-leaved saltbush, it often forms a large part of the hay cut on the native meadows, and develops to almost an alarming extent in cultivated fields which are inclined to be too salty for ordinary crops.

PAHUTE WEEDS (*Dondia depressa erectia* and *D. duffusa*).—Both of these plants are much branched, narrow-leaved annuals, or, at most, biennials. The common name by which they are designated in this region is said to be derived from the fact that the

Pahute Indians were in the habit of collecting the seed and using it for food. The plants are of rather questionable forage utility, although said by some to be relished by cattle after the late autumn frosts. Like the last species of saltbush, these often grow very vigorously in cultivated fields which are slightly too alkaline for cultivated crops.

Hop sage (*Grayia spinosa*).—A well branched shrub, 1 to 3 feet high, with long, slender spines, thick, rather succulent leaves, and a spike of winged fruits which bear some resemblance to the cultivated hop from which is derived the common name. This is seldom eaten in summer, but in the winter the leaves and fruit which fall in late summer are picked up by stock in much the same manner as they eat the leaves of the mesquite further south on the Arizona deserts. It grows in situations similar to the spiny saltbush, and is of value as autumn and winter feed.

White sage (*Eurotia lanata*).—As it grows in this region at the present time this is a low shrub, one-half to 2 feet high, consisting of a few straight unbranched shoots from a woody stump. It was formerly of much importance as a winter feed for both cattle and sheep, but the quantity is so reduced at the present time that it can not be considered of much economic importance.

Red sage (*Kochia americana*).—A sparingly branched plant, one-half to 2 feet high, with straight, slender, leafy twigs. Next to the white sage this is said to be the shrub most relished by cattle of any in the region. It is quite abundant in places from the higher bottoms to the foothills. After the advent of frosts in the fall the whole plant turns red—a characteristic which has given rise to the common name. The previous year's wood always bears evidence of having been eaten.

Greasewood (*Sarcobatus vermiculatus*).—A tall, brittle, wooded shrub with spreading branches and narrow, thick, succulent leaves. It always inhabits strongly alkaline ground and often grows where nothing else but the iodine weed (*Spirostachys occidentalis*) is able to thrive. Very large areas of this are found between Winnemucca and Quinn River Crossing. It is really the prominent lowland shrub in places and does not often bear evidence of browsing, but the leaves are cleaned up off the ground where they have fallen, and it is said to furnish much feed in this way. It can, however, be considered only an emergency ration at best. The feed it furnishes is both small in quantity and poor in quality. (See Pl. XII, fig. 2).

THE CLOVERS.

One of the main differences between the meadows and river banks of this region and corresponding situations in the Dakotas, eastern Montana, and Wyoming is the presence of numerous species of clovers of great importance in the economy of the stock industry. They furnish much valuable pasture and hay of excellent quality. The most important species are discussed below, although no attempt is made to give a comple list.

Seaside clover (*Trifolium involucratum*).—This is the most abundant and important of any of the native species of the region. In the low, swampy, nonalkaline areas on the native meadows it often yields from one-half to 1¼ tons of hay per acre. On the Divine Ranch it had spread, under the influence of irrigation, to sagebrush soil, and there, with timothy and redtop, made a fine crop. It is a promising species for cultivation and under proper treatment it would probably make feed about equal in quantity and quality to alsike clover.

Small-headed clover (*Trifolium microcephalum*).—Although not of as much importance as the previous species, this furnishes much pasture in places and it stands close grazing very well indeed. It is commonly found with the preceding species in low, wet meadows.

Beckwith clover (*Trifolium beckwithii*).—This is a larger, more rigid, and coarser plant in every way than either of the two previously mentioned. We found it at higher elevations than the others, usually in mountain valleys and meadows, along streams, and near springs. It was most abundant in portions of Silvies Valley. It is valuable mainly as a native pasture plant.

Oregon clover (*Trifolium oreganum*, No. 601).—A valuable mountain pasture plant. It is very common in mountains, where it often forms, with tufted hair grass (*Deschampsia caespitosa*) and Sandberg's blue grass (*Poa sandbergii*), a very respectable covering over the ground in small depressions and along banks of streams, and is always closely cropped in such situations.

Shield clover (*Trifolium cyathiferum*).—A common and occasionally abundant species forming much pasture along streams and moist localities. It is easily recognized by the large shield-like bracts below the heads of flowers.

THE SEDGES AND RUSHES.

When quantity alone is considered this group of plants is the most important of any in the region. Two or three species of sedges or rushes often take possession of large areas of the low, poorly drained, swampy basins and river bottoms. Although the quantity of feed from this source is large, the quality is ordinarily much inferior to that derived from the true grasses and clovers, and in some cases it is questionable whether the forage furnished by many of these plants is worth the cutting. Usually, however, the feed derived from the sedges (*Carex* sp.) is of very good quality, but on the whole rather light in weight.

Wire grass (*Juncus balticus*).—Every rancher knows this tough, wiry, leafless plant, which is almost invariably found in greater or less quantity in the lowland hay meadows. It is therefore very extensively cut for hay along with other forage plants, but it furnishes a very poor quality of feed.

Nevada rush (*Juncus nevadensis*).—This species often furnishes some pasture and a little hay along the edges of moist bottoms.

Toad rush (*Juncus bufonius*).—A low-spreading, much-branched plant growing in edges of ponds and very wet places. It is often pastured where better feed is scarce.

Creeping spike rush (*Eleocharis palustris*).—This is also often referred to as wire grass. It is very abundant on all of the lower meadows, and, like the wire grass, is often cut for hay. It is neither so harsh nor so rigid as the latter. Nowhere on the trip were such areas of it encountered as on the Malheur Lake bottoms, where much of it was cut along with other crops.

Awned cyperus (*Cyperus aristatus*).—This is quite abundant on sandy banks of the tributaries of the Malheur River, where it furnishes some pasture, but never any hay.

Red-rooted cyperus (*Cyperus erythrorhizos*).—This is often found in hay in considerable quantities on the low, wet, nonalkaline meadows along streams in southeastern Oregon.

Tule (*Scirpus lacustris*).—This is the most conspicuous plant on the bottoms. It often grows to a height of 15 feet, and the culms are often three-fourths of an inch in diameter. Pl. XV, fig. 2, shows this plant as it grows over very extensive areas on the Malheur Lake bottoms. In the more moist areas it is used simply as a browse and shelter for cattle during storms, but in the edges of the lower areas, where it grows to a height of 1 to 4 feet, much of it is cut with other hay crops, with which it is mixed. The quantity of feed from this source is probably

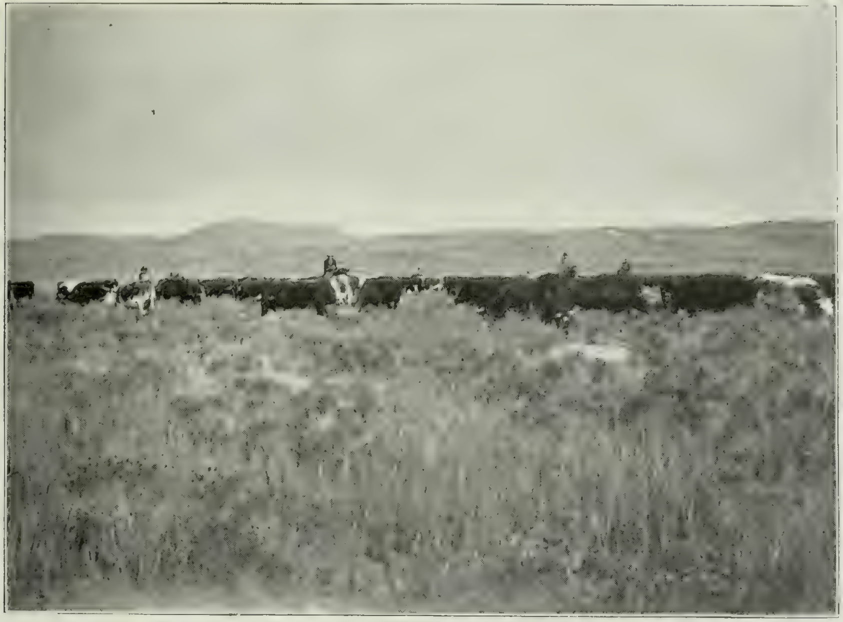

FIG. 1.—A PART OF A DAY'S ROUND-UP OF BEEF, SILVIES VALLEY, OREGON.
Smoke from a forest fire shown along the horizon.

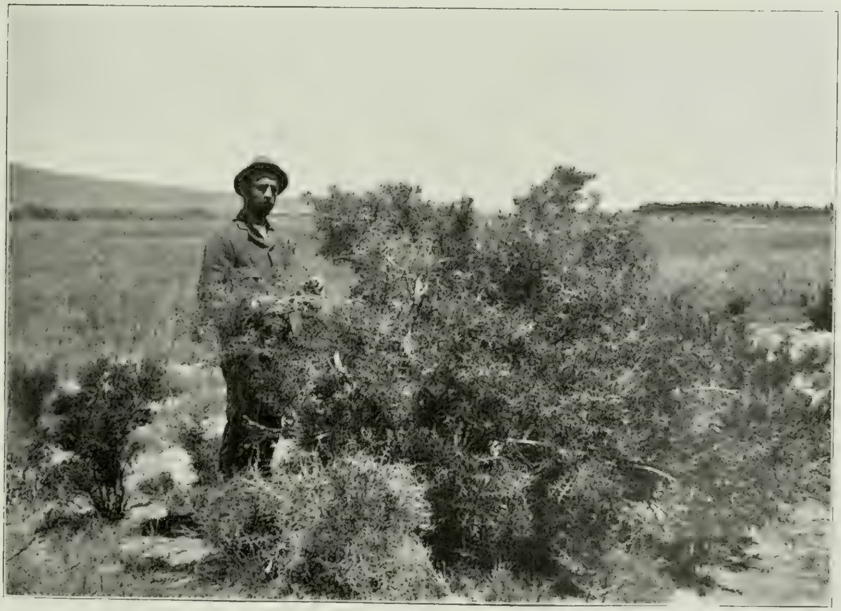

FIG. 2.—A WELL-DEVELOPED GREASEWOOD BUSH NEAR WINNEMUCCA, NEV.

considerable, but the quality is very poor. The seeds are nutritious, and one may often see horses in the tule patches in late summer picking off the heads.

Prairie bulrush (*Scirpus campestris*).—A brown-headed, triangular-stemmed, large, coarse, grass-like plant, growing in low, wet, and often alkaline meadows. The quantity of forage yielded by it is very large, and the quality, while not as good as that furnished by the grasses, is still very fair. Closely related species furnish large quantities of hay in many localities on lake and river bottoms in the Dakotas. In the vicinity of Divine's ranch, at the edge of the Alvord Desert, there was a very fine growth of this rush. Pl. VII, fig. 1, shows a very ordinary development of it, and also something regarding the character of the soil on which it grows. This particular spot would cut one and three-fourths to two tons per acre. In some places in this vicinity hay consisting of about two-thirds of this rush and one-third tule was cut in large quantities. The yield was often three tons per acre of very bulky forage.

Small-seeded bulrush (*Scirpus microcarpus*).—This is frequently found in large quantities in low, wet, nonalkaline areas. It is never in such quantities nor in such situations that it can be cut for hay, but it forms much of both winter and summer pasturage. It was first met with in the vicinity of Pine Forest Mountains, and frequently from there north.

Three-square (*Scirpus pungens*).—A triangular stemmed plant, with a small lateral head and few leaves, growing thinly, and propagating by creeping root stocks in wet and often alkaline localities. The same species is very commonly found in considerable quantities in the hay meadows in Wyoming, Montana, and the Dakotas. It is cut and pastured, but it makes a quality of feed but little better than the tule.

Awned sedge (*Carex aristata*).—This sedge furnished a great deal of pasturage and feed on the Malheur Lake bottoms. It grows in rich, moist, nonalkaline areas to the extent of one and a half to two tons per acre. Where we saw it the individual areas in which it grew were not large, but frequent, and measured from one-fourth to three or four acres. It furnishes by far the best and largest quantity of hay of any of the sedges in this region.

Douglas sedge (*Carex douglasii*).—This conspicuous, yellow-headed, wiry plant is probably the most common of all the species of the sedge family. It is invariably found on the drier bottoms, where it grows oftentimes to a height of 8 inches. Much of it, therefore, gets into the haystack, where it is readily eaten in winter, although it is very tough and wiry. On the open range it is always closely grazed. Its main value is for pasture.

Gay's sedge (*Carex gayana*).—This often forms from one-fourth to one-third of the hay in some localities. It was decidedly abundant in the vicinity of the Alvoid Desert, where, together with the Nebraska sedge and seaside clover, it yielded about one and a half tons per acre. Nowhere else was it found in such abundance.

Woolly sedge (*Carex lanuginosa*).—Commonly found mixed with the tule, but it thrives best in soils immediately surrounding the latter. It very often grows in situations too wet to be cut, but even here it furnishes feed for winter pasture. On the lower wet meadows on the Divine Ranch it formed about two-thirds of the crop over very large areas, the remainder being furnished by the Nebraska sedge and the seaside clover. It is also an important factor in the hay supply on both the Quinn River Crossing and White Horse ranches.

Clustered field sedge (*Carex marcida*).—Two varieties of this species are common in northern Nevada and southern Oregon. They are never abundant enough to form any great amount of hay in any one place, but in the aggregate, over large areas of the drier meadows, they amount to a great deal. When the drier meadows are too short to cut it is pastured in the winter with other sedges and grasses.

Nebraska sedge (*Carex nebraskensis*).—A very valuable pale-green species growing in low situations which are covered with water until late in the season. The hay which it furnishes is rather light, but usually considered of fair quality for this class of plants. It may grow alone over considerable areas which dry in midsummer and bake very hard, or it may be found with other closely related species and some clovers. The latter, of course, very materially improve the quality of the hay. (See also under Gay's sedge and Woolly sedge).

Soft-leaved sedge (*Carex tenella*).—This slender-culmed species furnishes a great deal of pasture in shady places in the mountains.

Bottle sedge (*Carex utriculata*).—Common in moist meadows, where it is both pastured and cut for hay. It was not collected in Nevada but was of considerable importance on the meadows of Silvies Valley and the north fork of the Malheur River, near Beulah, Oreg.

MISCELLANEOUS.

Horkelia fusca.—This glandular, strong-scented plant with numerous compound root leaves is an important sheep plant. It is very abundant in Steins Mountains and almost invariably bears evidence of being grazed. Cattle, however, in all probability never touch it.

Prairie vetchlings (*Lathyrus decaphyllus* and *L. Oregonensis*).—Grow very profusely in some localities and are to some extent found in hay in the Alvord Desert basin. We saw no evidences of their being pastured, however.

Dakota lotus (*Lotus americana*).—This plant, so abundant on all the river bottoms and low prairies in the Plains region, was not encountered until we reached the Snake River at Ontario, Oreg. Here it was very abundant and bore evidence of being grazed in many of the poorer pastures. It is very seldom indeed that the writer has seen this condition. Usually it, like the lupines, remains untouched in pastures, although readily eaten in hay.

Lupines.—These conspicuous blue-flowered plants, belonging to the pea family, are very numerous and characteristic of the western plains, mountains, and even deserts. They are usually considered of some value, and are therefore included here. It has not been the writer's experience, however, that they are eaten much by cattle. Sheep occasionally do eat them in poor pastures, but their destruction by the sheep is due more to trampling than to actual eating. About ten species were collected, two or three of which are very common, and might be mentioned in a list of forage plants. The most important are *Lupinus lepedus* and *Lupinus laxiflorus.*

Bur-reed (*Sparganum eurycarpum*).—A broad-leaved grass-like plant with prominent globular masses of fruit produced in late summer. This very common plant in all the wet meadows of the regions is of more economic value here than in any locality the writer has ever visited. It is often cut with the tule, sedges, and rushes for hay, and is commonly pastured where stock can get at it during the summer. It was especially abundant on the Malheur Lake bottoms where pure growths of it were often found. The team in Pl. XV, fig. 2, is standing in an area of this plant.

Seaside arrow grass (*Triglochin maritima*).—This salt-loving plant, with rush-like leaves and stout, erect, naked flower stalks, furnishes much pasture and occasionally a little hay along with the more valuable rushes and sedges. It is found only in very moist alkaline regions, and is an invariable occupant of the saline regions in the vicinity of hot springs.

Cat-tail (*Typhia latifolia*).—This conspicuous and universally recognized swampland plant furnishes much winter feed, and occasionally some of it is cut for hay. A little of it is shown in the extreme foreground in Pl. XV, fig. 1.

American vetch (*Vicia americana* and *V. truncata*).—Are common and of some value on portions of the drier, rich, lowland meadows. Like the vetchlings discussed above, they are not pastured except where the sedges, grasses, and clovers fail.

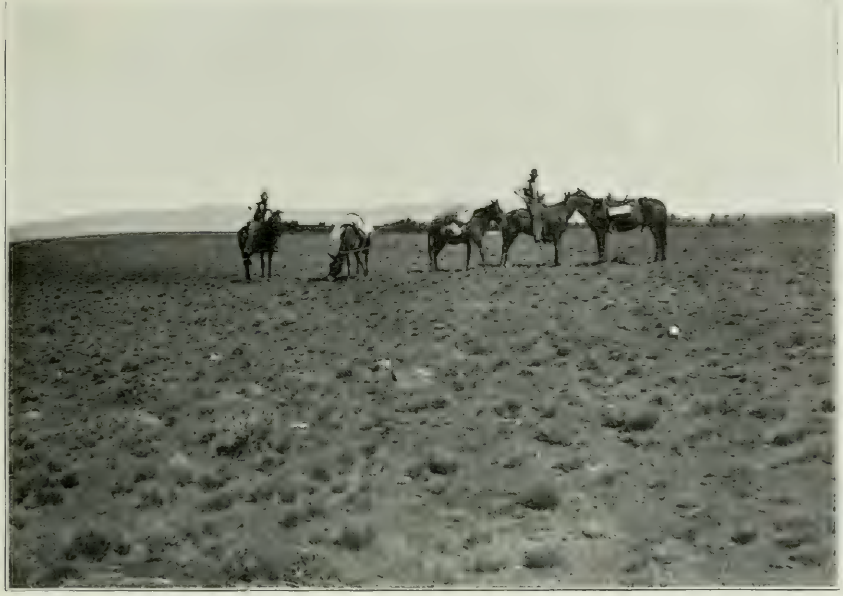

FIG. 1.—A MODERATELY GRAZED NATIVE PASTURE IN STEINS MOUNTAINS, OREGON.

Stubble of sheep fescue constitutes nearly the entire vegetation in foreground.

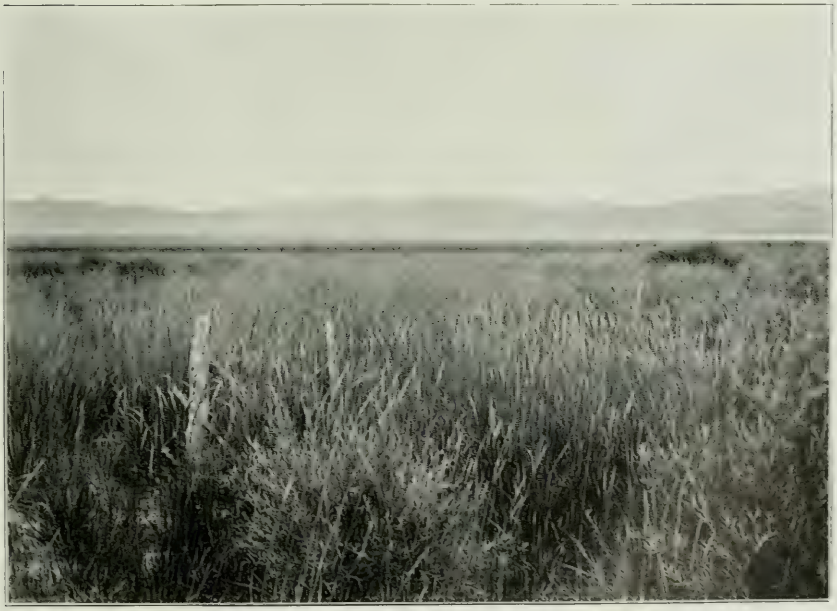

FIG. 2.—A GIANT RYEGRASS MEADOW, QUINN RIVER CROSSING, NEVADA.

Alfilaria (*Erodium cicutarium*).—This forage plant, which is of so much importance on many of the Arizona and California arid pastures, was seen in considerable quantity along the western base of the Pine Forest Mountains in Nevada and at Denio, Oreg., but it is very doubtful whether it is abundant enough to be of much value.

THE GRASSES.

Short-leaved wheat grass (*Agropyron brevifolium*).—Occasional in Steins Mountains.

Awned wheat grass (*Agropyron caninum pubescens*).—A common species in the mountains. It forms some pasture at moderate elevations, especially in the Pine Forest Mountains.

Western wheat grass (*Agropyron occidentale*).—This forms a scattering growth in the lower sage-brush areas. It seldom, if ever, grows on the lower alkaline soils. It is of very little importance here compared with the plains region. The variety *molle* grows in similar localities.

Western couch grass (*Agropyron pseudorepens*).—Common in the rich, drier meadows, but never forming the quantity of feed that it does east of the Rocky Mountains.

Bunch wheat grass (*Agropyron spicatum*).—This is the most important wheat grass of the region. It is an awned grass, and grows almost invariably in rocky but fertile soils in the upper foothills and mountains. Although rather harsh and wiry, it furnishes much valuable feed for summer and autumn pasture.

Slender wheat grass (*Agropyron tenerum*).—Although common on the richer, well-drained lowland areas throughout the region and of some importance as a pasture and hay grass, it amounts to but little compared with the plains region, where it furnishes such magnificent pasturage and hay.

Water foxtail (*Alopecurus geniculatus*).—A low, smooth, tender grass with weak stems, which often root at the joints. It is found abundantly throughout the region, along streams, and in wet meadows which are not completely sodded over with the sedges. It furnishes good pasturage, but the quantity of hay is of little consequence.

Redtop (*Agrostis alba*).—Doubtless some forms of this widely distributed and valuable forage plant are indigenous, but it is so widely distributed in all meadows that the introduced form often appears native. It is well adapted to the poorly drained, boggy areas, and it is believed that it could be more extensively introduced with great profit.

Rough hair grass (*Agrostis hyemalis*).—A slender, smooth grass with delicate panicle, furnishing some pasture in moist mountain meadows, as well as upon the lowlands. The quantity of its hay is small, but the quality good. On the low meadows of the White Horse Ranch much of it was found in the hay. Probably as high as a fifteenth of the entire bulk consisted of this grass in limited localities.

White top (*Agrostis exarata grandis*).—An erect, smooth, rather tall grass, growing usually in loose bunches. It is of much value for both pasturage and hay and is relished by all stock. It is never abundant enough to make a crop itself, but it often forms an eighth or tenth of the bulk of the forage on the low meadows.

Slender bent grass (*Agrostis variabilis*).—A tufted, slender mountain species which furnishes much pasture in moist meadows. It was especially abundant in Steins Mountains, where it often furnished good feed in rather dry localities. It is always more or less abundant in all the depressions and along streams.

Purple bent-grass (*Agrostis humilis*).—A slender, purple-topped, tufted species, growing in moist places in mountains. It furnishes some feed in the vicinity of streams and lakes in the Pine Forest Mountains.

Hall's redtop (*Agrostis hallii*).—An erect grass, resembling closely the common redtop, but with a more open and delicate panicle. It is a valuable hay grass in the Alvord Desert region, especially on the White Horse and Divine ranches. In some meadows on the former it replaces to a very large extent the common species of redtop, and forms, in limited areas, a fourth of the crop of hay, the remainder being made up of seaside clover and several sedges.

Wild oats (*Avena fatua*).—This grass, which is such a pest in many small grain-growing regions, has been mentioned under weeds. Several fields of first and second crop alfalfa were seen in which this formed a third to a fourth of the forage. One or two years of alfalfa cropping will usually rid the land of it, however.

Slough grass (*Beckmannia erucæformis*).—A common species all through the region, but never abundant enough to be of any importance as a hay plant, as it is oftentimes in western Montana, especially in the Flat Head Valley. Here it forms simply a scattering growth in moist places along ditches and streams, and is of value only as a pasture grass.

Keeled brome (*Bromus carinatus*).—A stout, erect, tufted, perennial grass, abundant in all the mountain regions. It usually grows in steep, rocky places with bunch wheat grass, Buckley's blue grass, and sheep fescue, and forms large quantities of feed in such localities. It is especially abundant in Steins Mountains on the side of Teger and Blitzen gorges.

Short awned brome (*Bromus marginatus*).—This species, although extending into the mountains, makes its best growth in partially cultivated ground on the lower levels. At Big Creek and about 10 miles south of Burns there were exceptionally fine growths of it in many fields. It is the most promising of the native species of this genus for cultivation.

Hairy brome (*Bromus subvelutinus* No. 617).—This strikingly hairy species was found in only one locality, but there it formed about a sixth of the entire pasture growth, the remainder being Buckley's blue grass and bunch wheat grass. The locality was a southern, rocky exposure in Steins Mountains, about one-half mile below the gorge on the Blitzen.

Introduced species of bromes.—Four species not native to this country are introduced in this region in considerable quantity. In limited localities these vie in importance with the native grasses, and wherever found they are valuable forage either as hay or pasture. Usually, however, they assume the character of weeds. The most common of these forms is, of course, the common cheat (*Bromus secalinus*). The appearance of three species of this genus along Bartlett Creek in northern Nevada was very interesting. There had been some prospecting in the valley and seeds of *Bromus rubens*, *Bromus hordeaceous*, and cheat (*Bromus secalinus*) had evidently been introduced with feed from California points. These species had literally taken possession in some portions of the valley. Being annual species, however, they dry up early in the summer and are then not relished by stock.

Yellow fox tail (*Chætochloa glauca*) and Green fox tail (*Chætochloa viridis*).—Are sparingly introduced. Nowhere did we see them thriving with any degree of vigor.

Blue joint (*Calamagrostis canadensis acuminata*).—Occasional on low, moist meadows. It is never very abundant, but makes good feed wherever found.

Yellow top (*Calamagrostis hyperborea americana*).—A very important, erect, rather wiry grass. Yellow top grows well on low, moist meadows. The best growth of it the writer has ever seen was on the Malheur Lake bottoms, where there were areas of an acre or more in places almost pure. It was always found along the edges of the lower bottoms and, according to soil tests, in nonalkaline soil. A large quantity of seed was secured from the Island Ranch, south of Burns, Oreg.

Tufted hair grass (*Deschampsia cæspitosa*).—This is an important forage in the moister localities in all the mountain ranges. It stands close pasturing very well,

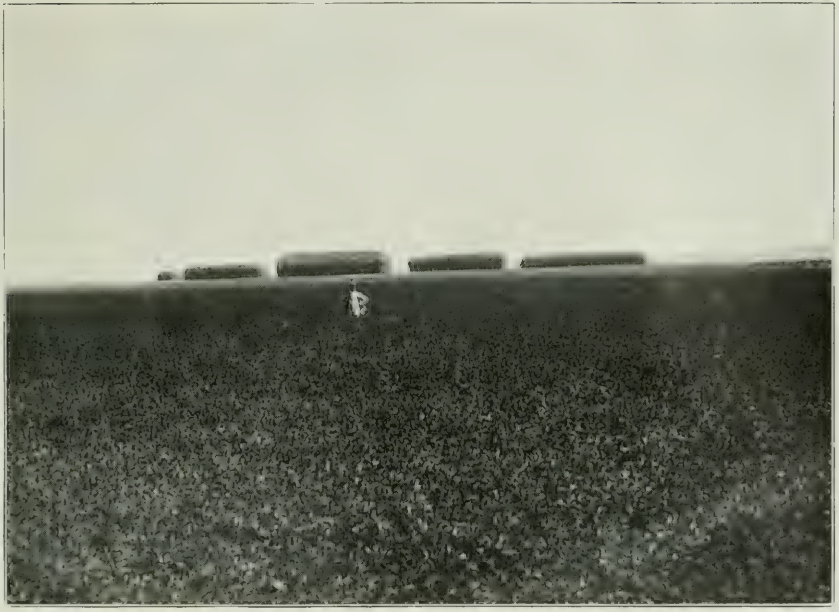

FIG. 1.—FOUR WEEKS' GROWTH OF SECOND-CROP ALFALFA, NEAR ONTARIO, OREGON.

Field said to have produced 10 tons of hay on three cuttings last year.

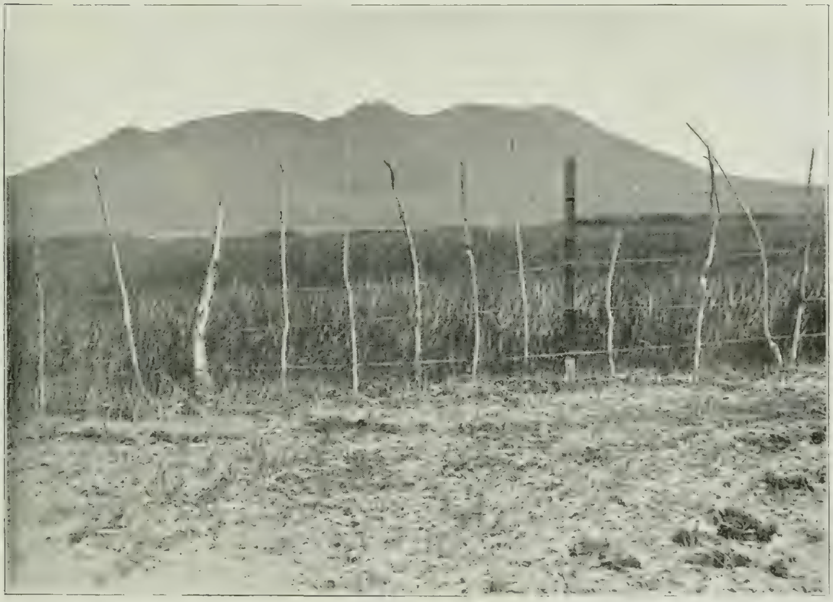

FIG. 2.—WILD WHEAT NEAR WINNEMUCCA, NEVADA.

Closely pastured meadow of same grass in foreground.

and when kept cropped it makes a good quality of pasturage. It is also often present on the lower meadows.

OAK-LIKE HAIR GRASS (*Deschampsia calycina*).—Like the last species, this has a wide habitat, ranging from the lower bottoms to the higher mountains. It was found in abundance on the White Horse Ranch, where there were acres of it. Although rather short, it had been cut for hay in places. It furnishes pasture early in the summer, but being a rapidly growing annual, it dies and dries up early in the season, and is then not relished by stock. It had all died and dried up some time before we visited the region on the 1st of August.

SLENDER HAIR GRASS (*Deschampsia elongata*).—Decidedly a mountain grass. While not of nearly as much importance as the tufted hair grass, it furnishes a great deal of feed in low, wet meadows, and especially in the vicinity of mountains, brooks, and springs.

SALT GRASS (*Distichlis spicata*).—This familiar grass on all the Western plains and basin region, while very rigid and wiry, is one of great importance. Its persistent habits of growth, its power to resist close grazing and drought, its very ordinary feeding qualities and its ability to thrive in strongly alkaline soils are qualities which make it a very valuable emergency feed. Were it not for this persistent grass many more cattle would die of starvation than do. It makes a very ordinary feed, but it is this very characteristic that makes it valuable. Were it more highly relished by stock it would probably have been exterminated long ago. It was a common thing to find it closely cropped all the way from Winnemucca to Ontario. Large herds of cattle were apparently subsisting on this and squirrel tail (*Hordeum jubatum*) on the open range on the Malheur Lake bottoms in August.

GIANT RYE GRASS (*Elymus condensatas*).—This mammoth, erect, usually more or less tufted species is one of the most important grasses of the drier basin bottoms. There are thousands of acres of it fringing the bottom lands and often extending outward into the sagebrush areas. Pl. XIII, fig. 2, shows a characteristic growth of it in the Quinn River Valley, almost hiding a wire fence. It grows on the drier and, according to soil tests, nonalkaline areas. It is very often cut for hay, but more often it is left for winter pasture. It is very valuable in stormy weather, for its habit of growth prevents its being covered with snow. It is claimed by ranchers that it does not stand cutting and close pasturing well. Under these treatments it gets thinner and thinner and eventually disappears. The areas of it are said to have greatly diminished in recent years. Horses fare especially well on it from the middle of July to the middle of September. When allowed to pasture in the fields at this time of the year they live almost entirely on the rich seed supply, roaming over the fields and picking off the heads. Although it is often very badly ergoted, no evil effect is reported on this account.

MOUNTAIN RYE GRASS (*Elymus glaucus*).—This abundant species of the Rocky Mountain region is common here. It grows scatteringly among the shrubbery in the mountains.

WILD WHEAT (*Elymus triticoides*).—This is the blue stem of this region, a name by which it is universally recognized by the ranchers. In many respects it is the most important grass of the entire region, and is a very promising species for cultivation. The seed is produced in abundance and is invariably well filled and easily gathered. Its habit of growth is very similar to that of the western wheat grass of the plains region and the quality of the hay produced by the two are probably about equal. There were magnificent crops of it along the Humboldt and Quinn rivers, in the Alvord Desert basin, and on the Malheur Lake bottoms. It grows in rich, nonalkaline, heavy soils, and where properly watered it often yields 2 to 2½ tons per acre. It appears to be well adapted to the damming and flooding system of irrigation in vogue here, for it stands submerging to a greater degree than the majority of the native grasses. Large quantities of seed were secured along the Humboldt and Quinn River bottoms. Pl. XIV, fig. 2, shows a characteristic growth of it on the Humboldt bottoms near Winnemucca. The picture was taken from a closely cropped pasture of the same grass.

CANADIAN RYE GRASS (*Elymus canadensis*).—Common and furnishing a great deal of pasture in the edges of thickets and along streams, especially to the northward.

EARLY BUNCH GRASS (*Eatonia obtusata*).—A valuable species wherever found, but its quantity is rather limited on these bottoms.

INDIAN MILLET (*Eriocoma cuspidata*).—A low bunch grass with white, woolly spikelets and very divergent and usually crooked, irregular panicle branches. It inhabits sandy areas skirting the river bottoms and requires a loose, porous soil for its best development. It was much more abundant in former times than it is now. The readiness with which it is eaten and the loose soil in which it grows render it very susceptible to injury from overstocking. It was pointed out to us on several occasions as having been a very valuable grass at one time, but now it is of little importance.

CREEPING ERAGROSTIS (*Eragrostis hypnoides*).—A prostrate, creeping annual which furnishes some pasture in low, wet places.

SLENDER FESCUE (*Festuca octoflora*).—A small, short-leaved, annual grass which grows early in the spring, and, after maturing a large crop of seed, dies with the approach of dry weather. The species is to this region what the six weeks grass (*Bouteloua aristidoides*) is to the Arizona deserts. The latter, however, grows in July and August instead of in the spring. It is common all over the mesa region between the lowland and the higher foothills and doubtless furnishes much feed early in the season. It is usually considered of practically no value. We found it especially abundant in the lower foothills in southern Oregon.

SHEEP FESCUE (*Festuca ovina*).—Reference has been made to this valuable mountain species in several places on previous pages. As a pasture grass it is one of the most important of the native species. It is certainly surpassed by none in either the quality or quantity of feed produced, unless it be Buckley's blue grass. It has, in this region, two well-marked and distinct forms which are as different in their habits as in their general appearance in the field. One, which is entirely smooth, occupies the areas of the mountains situated between the upper foothills and the higher elevations. In the lower portion of this area it is mixed with Buckley's blue grass, but higher up there are large areas upon which practically no other grasses grow. The other, growing on the highest elevations, is the typical glaucus form of the Rocky Mountain region. Magnificent areas of this form were seen in the vicinity of Bartlett Peak and in the Pine Forest Mountains. In the former locality there were stretches on the top of the mountains above the snowdrifts a mile in extent where there was practically no other grass. Only two small areas were found which had not been pastured.

CUT GRASS (*Homalocenchrus oryzoides*).—This is common on ditch banks and along streams from the Malheur Lake region north. It was not collected south of this point. It is pastured somewhat, but can not be considered of much value.

SQUIRREL TAIL GRASS (*Hordeum jubatum*).—Usually this species is considered a vile weed and is a great detriment to many native hay meadows of this region. But while this is true, it also furnishes a large quantity of excellent pasture in many regions. On the Malheur Lake bottoms there are thousands of acres where almost no other grass grows. On the open range it was invariably cropped close to the ground. An occasional fenced area showed wonderful stands of it. One field seen would certainly have cut a ton of this grass to the acre. The analysis of the soil samples taken from this region shows that it develops to the best advantage on soils which do not contain alkali in quantities injurious to cultivated crops; it is certainly neither so hard nor so compact as the soil in the surrounding and contiguous areas where salt grass abounds.

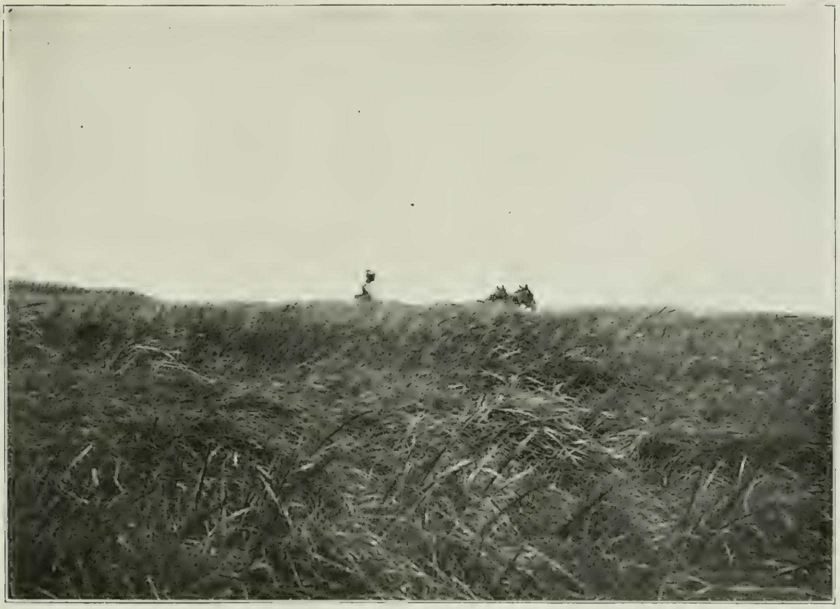

FIG. 1.—SPRANGLE TOP (SCOLOCHLOA FESTUCACEA) ON MALHEUR LAKE BOTTOMS, OREGON.

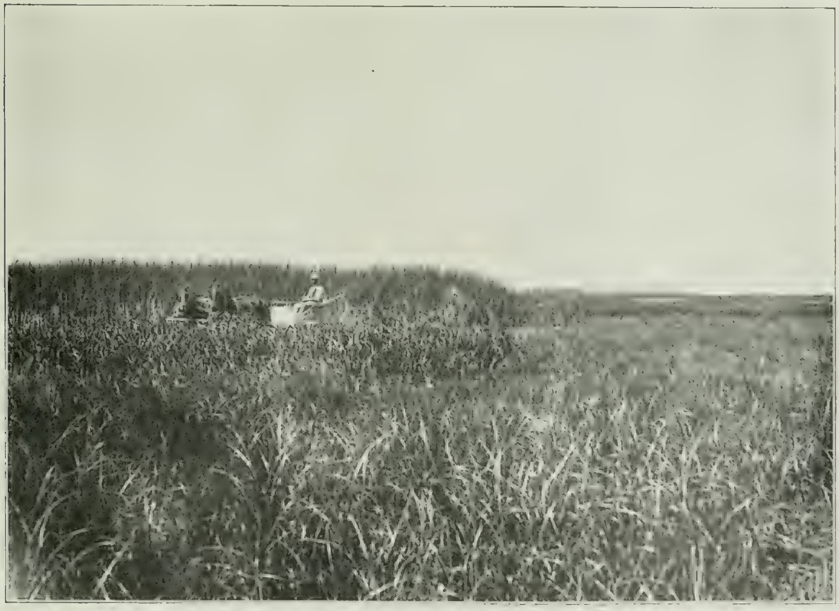

FIG. 2.—A PATCH OF TULE ON MALHEUR LAKE BOTTOMS, OREGON.

The team is standing in a patch of bur-reed (Sparganum).

Meadow barley (*Hordeum nodosum*).—The bearded fruits of this are probably not injurious to stock which eat it; at least no positive records are at hand of its doing any injury in this way. It enters into the composition of the hay very largely in many native meadows. Among shrubbery on the bottom it makes a very tall growth, and in such localities, where the mower can not be used, it enters largely into the composition of the winter pastures.

Seaside barley (*Hordeum maritimum*) and Wall barley (*Hordeum murinum*) are shorter lived than the other two species and are therefore of less value. They furnish some pasture early in the season, but usually are as little prized as the slender fescue.

Prairie june grass (*Koleria cristata*).—This is distinctly a mountain grass in this region. It usually grows to best advantage in the rich soils of rocky gulch sides, where it often forms from one-eighth to one-sixth of the pasturage.

Bulbous melic grass (*Melica bella*).—A very common species with a bulbous base resembling that of the common cultivated timothy. It is never very abundant, but grows rather sparingly among mountain shrubbery, where it furnishes good, although limited, pasturage.

Muhlenbergias (*Muhlenbergia comata* and *M. sylvatica*).—Common along streams in protected places and along irrigating ditches, and furnish a limited quantity of pasturage.

Reed meadow grass (*Panicularia americana*).—A swamp-land species which occasionally furnishes a little hay, but which is of most value as a pasture grass. It is abundant along the Malheur River and its tributaries.

Manna grass (*Panicularia pauciflora*).—More of a mountain form than the former species. It is always present in wet, rich soil, along streams. In the White Horse and Pine Forest mountains it was especially abundant.

Barnyard grass (*Panicum crus-galli* and the variety *muticum*).—While common in wet and waste places all through the region, it was nowhere so abundant as on the Harper ranch, 40 miles above Ontario, Oreg., on the Malheur River. It was considered a bad weed here because it had taken possession of a first-year field of alfalfa. Pl. XVI, fig. 1, shows a volunteer crop of it in this vicinity. The failure was evidently not caused by the development of this grass, but was due in the largest measure to overirrigation, water having stood on a portion of the field for from two to five days, according to reports. This furnished just the condition necessary for the growth of this grass, and at the same time one which was fatal to the alfalfa. The lower areas in this field yielded at least 2 tons of dry hay per acre of this grass.

Reed canary grass (*Phalaris arundinacea*).—A tall, handsome, lowland species, often called wild timothy. It is frequent all through the region, but apparently of little importance as a hay grass. It furnishes some pasture among the tule patches and sedges and rushes on the lower bottoms.

Mountain timothy (*Phleum alpinum*).—This is a very valuable grass, differing but little in ordinary appearance from the common cultivated species, except in size. It furnishes a great deal of pasture in the moist mountain meadows all through the region.

Reed grass (*Phragmites vulgaris*).—This was found in but one locality, and that along Bartlett Creek, some distance up the mountains from the upper end of the Black Rock Desert.

Buckley's blue grass (*Poa buckleyana*).—This common "bunch" grass is one of the most important native pasture species. It grows from the lower foot hills to the mountains and furnishes pasture much earlier than the fescues of the higher elevations. No distinction appears to be made here between these two grasses, both the blue grasses and the fescues being designated by the term "bunch grass." It grows almost pure on the lower elevations, but higher up it is mixed with the smooth form of sheep fescue.

BUNCH BLUE GRASS (*Poa laevigata*).—A smooth, erect, light-colored grass, related to the Kentucky blue grass. It inhabits the drier, nonalkaline bottoms, and is a very excellent species for both hay and pasture. The meadows of it which were seen were very uneven, due no doubt, in a large measure, to overpasturage. Many small areas on the bottoms, however, would cut one to one and a half tons per acre. The species is a very promising one for cultivation and the seed is easily gathered. The quality of both the hay and the pasturage furnished by it is excellent. The hay is much superior to that furnished by wild wheat (*Elymus triticoides*), but the yield is much smaller.

NEVADA BLUE GRASS (*Poa nevadensis*).—This handsome, bunch, glaucus blue grass is confined mainly to the mountains in this region. Occasionally a little of it may be found on the lowlands, but the quantity here is very small. It furnishes much pasture on the broad, gentle slopes in Steins Mountains, as well as on the rocky, steep canyon sides.

WOOD MEADOW GRASS (*Poa nemoralis*).—A common species in some mountains, but of little importance compared with the Rocky Mountain region.

KENTUCKY BLUE GRASS (*Poa pratensis*).—Forms of this valuable pasture and hay grass are common throughout the region from the lowlands to the high mountains. It was of greatest importance in the spur of the Blue Mountains, north of Burns, Oreg., where with Prairie June grass (*Koleria cristata*) and Nevada blue grass (*Poa nevadensis*) it formed in pine clearings in many places the entire grass forage. These three species were found here in about equal quantities.

WHEELER'S BLUE GRASS (*Poa wheeleri*).—This species is often found with Buckley's blue grass in the lower mountain canyons and ravines. It furnishes excellent feed for both cattle and sheep. It was especially abundant in Steins Mountains on the sides of Teger and Blitzen gorges.

BEARD GRASS (*Polypogon monspeliensis*).—Although an annual, this is a very important species on all lowlands. It furnishes a large amount of pasture and enters into the composition of the hay to a considerable extent. In some meadows examined it formed a fourth of the crop. The green feed is relished by stock and the hay when cut early is of good quality, though rather light. Pl. XVI, fig. 2, shows Arizona-grown plants of this species.

ALKALI GRASSES (*Puccinellia airoides* and *P. lemmoni*).—These species are not so abundant and important in this region as one would expect. They were found all through the region, but never in such quantities as along the Yellowstone River or in the Flathead Valley in Montana. The best growth seen was near Andrews, Oreg.

SPRANGLE TOP (*Scolochloa festucacea*).—This tall, bushy-topped, broad-leaved grass was not seen except on the Malheur Lake bottoms, where it forms tremendous quantities of hay. It is a common species in low, wet meadows from Iowa to Nebraska northward, but it is not usually considered of much value as a hay grass. In certain places, however, in the general depression of the low, swampy ground in eastern South Dakota, especially in the vicinity of Clark, large quantities of hay are yielded by it in dry seasons. It is rather astonishing that it should be found again in this place in such large quantities. Quite extensive areas of it were seen which would yield three tons of hay per acre. Pl. XV, fig. 1, shows a typical area fully headed out. In the foreground it is lodged and mixed with bur-reed (*Sparganum eurycarpum*). Its habits of growth are similar to many of the valuable grasses of this and the Plains region, inasmuch as it develops by creeping rootstocks, and very often does not head out at all. This occurs in dry years and in the drier portions of the meadows in wet years. We drove through a half-mile stretch of it in one place on the Island ranch where the stand was fairly thick, 2 to 3 feet high and yielding 2 or 3 tons of hay per acre of very fair quality, although rather coarse and light. The hay being harvested as shown in Pl. VIII, fig. 2, is composed almost entirely of this grass and prairie bulrush (*Scirpus campestris*).

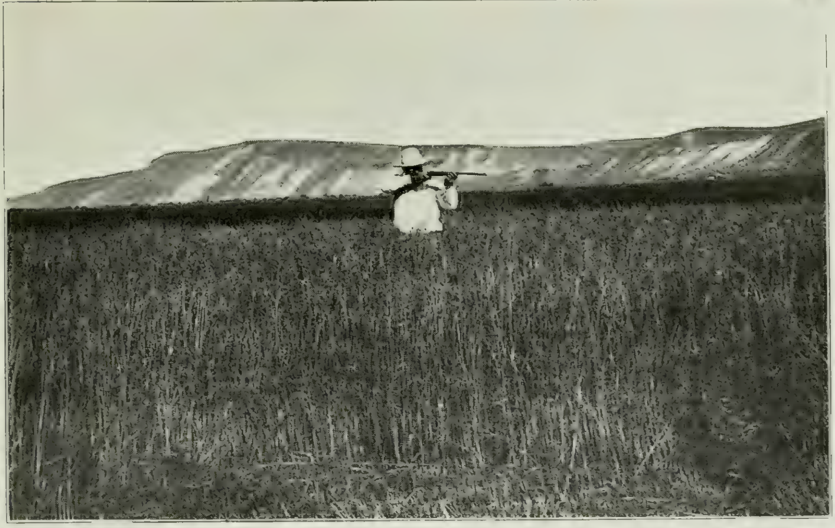

FIG. 1.—A VOLUNTEER CROP OF BARNYARD GRASS, HARPER RANCH, NEAR WESTFALL, OREGON.

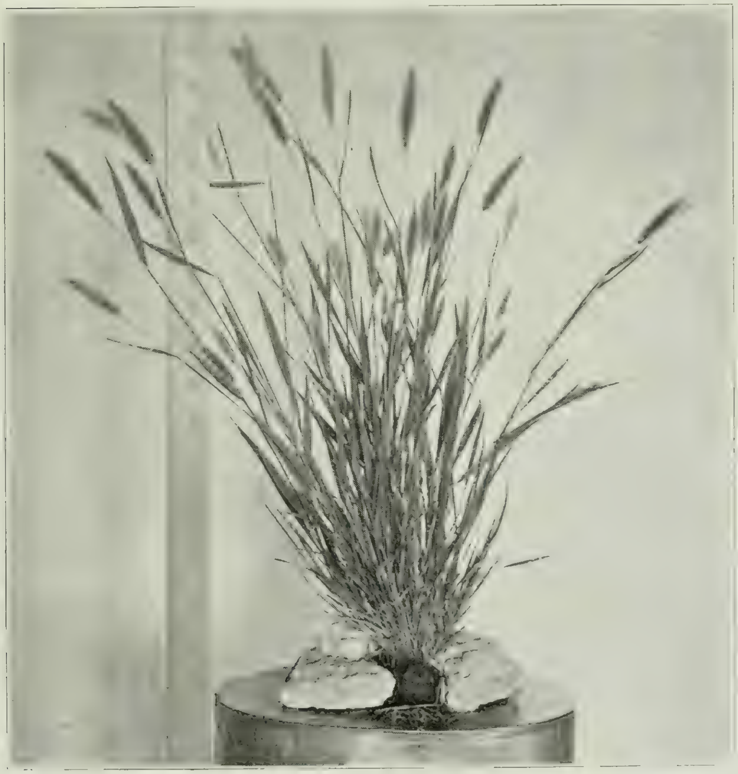

FIG. 2.—BEARD GRASS, FROM PHOTOGRAPH OF PLANT GROWING NEAR TUCSON, ARIZONA.

ORCHARD BARLEY (*Sitanion longifolium*, *S. cinerum*, and *S. hystrix*).—The first named is the most important. It is abundant all through the mountains and extends down to the upper bottoms. In regions frequented by sheep it was invariably cropped the same as other grasses. Cattle, however, do not appear to feed upon it so much. *S. cinerum* is a common species which furnishes some feed in the open clearings in the Blue Mountains, and *S. hystrix* is a mountain species which was collected only in the Pine Forest Mountains. Here, however, it appeared to be grazed fully as much as *S. longifolium*.

SMALL CORD-GRASS (*Spartina gracilis*).—An erect, rigid, wiry species common on all low alkaline meadows. It is commonly found with salt grass and alkali saccaton. The little pasture which it furnishes is probably but slightly superior to the salt grass itself. We found the greatest quantity of it in the Alvord Desert basin.

ALKALI SACCATON (*Sporobolus airoides*).—A very characteristic and often abundant species on the low, alkaline areas. According to soil sample taken north of Denio, Oreg., it grows on the white rather than the black alkaline soil. This corresponds with observations made in Arizona. Its habit of growth in this region is very similar to the appearance it presents in the Yellowstone Valley in Montana. In the Sulphur Spring Valley in Arizona, however, it grows very often to twice the height that it does here. For a rigid, tufted grass it appears to be relished by cattle, and is always closely cropped here on the open range. In places along the Humboldt River it enters into the composition of the hay to some extent, but its habits of growth render it of more value for pasture than for hay.

ROUGH-LEAVED DROPSEED (*Sporobolus asperifolius*).—A short, bright green species, with long, creeping-root stocks and a delicate, divaricate panicle, which is easily broken, both in the green and ripe stages. It never forms hay, but is an important pasture grass on many of the drier meadows.

DROPSEED (*Sporobolus depauperatus*).—An abundant, rather wiry, species on all of the drier bottoms. It often grows large enough to be cut for hay in favorable years, but its main value is for pasture, of which it furnishes a large amount.

NEEDLE GRASS (*Stipa comata*).—This species, so abundant and important in all the plains region, grows here most commonly on the lower mesas among the sagebrush. It is never abundant enough to form even a tenth of the soil cover, but the stray, luxuriant bunches of it form feed that is highly relished by stock.

SMALL NEEDLE GRASS (*Stipa minor*).—An abundant species among shrubbery and on shady slopes, especially in Steins Mountains. It forms here much valuable pasture. It never grows thick, but, like other species which inhabit bushy localities, it grows in scattered bunches among the other vegetation.

NELSON'S NEEDLE GRASS (*Stipa nelsoni*).—A common species in the White Horse Mountains, but never abundant enough to be of very much importance. The feed which it does produce is of good quality.

WESTERN NEEDLE GRASS (*Stipa occidentalis*).—Common and conspicuous in the mountains. It grows in large bunches much like the feather bunch grass of the plains region, and the quality of its feed is very similar to the latter.

DOWNY OAT GRASS (*Trisetum subspicatum*).—This furnishes a limited quantity of good pasture in the edges of thickets in Steins Mountains.

SUMMARY.

(1) The public ranges of the region are in many places badly depleted, and furnish at the present time not over one-third of the feed which they once did. This is directly traceable to overstocking, and it does not appear clear how matters will improve in this respect in the near future as long as there is no inducement for anyone to do aught but

get all he can out of the little that the country does produce. The areas of absolutely depleted range on the mountains, the most productive of any in the region and really the only grazing grounds, are rapidly increasing. The large stretches of country, especially in Steins Mountains, cleared of all semblance of forage during the past summer, will not produce as much feed next year as they did this with the same climatic conditions; and, with the present practices, which bid fair to continue, will become less and less productive each succeeding year.

In such rough mountains and stony regions no method of improvement having as its basis cultural operations are practicable. The only process of renovation and improvement of any kind that can be of utility is one that aims to control the pasturing in such a way as not to injure the stand of grass. The whole question of preservation and maintenance of native pasturage, therefore, is an administrative one. In regions which have suffered most from a lack of such administration, such as the grazing areas of the Southwest, the native grasses and other more valuable forage plants have been almost exterminated and their places supplied by weedy growths of much less value. Fortunately such transformations are slow to occur, but they are very difficultly remedied when once established.

(2) Clearing the ground of grass is not the only evil effect, as is well known. The destruction of the shrubbery, all too scanty in this region, has a potent influence on the lowland meadows and the mountains themselves, both in relation to the conservation of moisture and the protection of the surface soil from the erosive action of water. The destruction of the vegetation means vastly more than simply depriving cattle of food in the particular locality where close pasturing is practiced.

(3) The lowland meadows which yield crops of wild wheat or blue stem would, without doubt, be greatly benefited by simple cultural operations, even though no seed were sown. This grass, propagating as it does like the wheat grasses of the plains region, by means of creeping root stocks, would receive a great stimulus by having these underground stems cut at intervals, and by stirring up the ground, which becomes very hard during the summer, and is still more effectually packed by the trampling of cattle during early winter and spring. The seed of this grass, very easily collected, probably grows only to a very limited extent under present conditions, but, with light disking or harrowing, it might be used with profit to strengthen areas which have become weakened by repeated cutting and overstocking. There is no doubt that shallow disking, with a little scattering of seed of this grass, would very materially improve many of the native meadows. The areas which receive treatment would have to be very carefully selected, however. There would in all probability be very little use in

attempting to secure a stand of this grass all over the native meadows, but the areas which now produce some of this species, and formerly produced much more feed than they do now, might be greatly improved in this way. The same would apply with equal force to areas which produce bunch blue grass (*Poa lævigata*) and giant rye grass (*Elymus condensatus*), although the habits of growth of these grasses are very different. The seed of the giant rye grass is easily gathered, and, when not too badly affected by ergot, grows well. In an ordinary locality one man can gather a hundred pounds of clean seed of this grass in a day, using no other implement than an ordinary grass hook for the purpose. A vigorous man would have little difficulty in gathering fifty pounds of the seed of wild wheat in a day in at least three localities which we visited. It will be seen that this makes very cheap grass seed compared with the ordinary commercial species.

(4) Redtop (*Agrostis alba*), already established in places, could without doubt be more extensively introduced in many of the moister bottom lands. Instances have been cited where it was making a good crop, and it will without doubt grow well on the lowlands wherever the native clovers abound. It is one of the most promising plants for the improvement of portions of the bottom lands. No finer quality of hay could be desired than that which is furnished in localities at the present time by this grass and the native clovers.

(5) Mention has been made several times of the peculiar "patchy" condition of the native meadows and of the fact that the largest yield of forage is from plants which make hay of an inferior quality, such as the rushes, sedges, and wire grasses. The cause of this condition is in many cases absolutely beyond economical control at the present time. It is due largely to the effect of a too abundant supply of water in the early spring with practically none during early summer. Being located in the lower depressions in the basins, these lands can not be drained except at prohibitive prices to the majority of the holders. Where these lands can be drained without too much expense they could without doubt be made to yield more forage of a better quality than they do now. Either storing the spring flood waters and applying them later in the season or draining the low, swampy areas would produce beneficial results. Several instances of drainage on a small scale with beneficial results were called to our attention. The French-Glenn Company was installing a large dredging machine to be used in the Malheur basin when we were in the region.

(6) There are several conditions which interfere with the culture of alfalfa in this region, the first and foremost being too little water and improper methods of applying it. Other difficulties, however, are more under the control of the rancher and can usually be either avoided or obviated, namely, poor drainage and too much alkali in the soil. Usually there is an abundant supply of water in early spring, and

of course there is a temptation to use it too freely at this season, often resulting in allowing the fields or portions of them to remain flooded for three days or more at a time. In a number of instances attempts were being made to secure a stand of alfalfa on land which evidently contained considerable quantities of salt. While it has been demonstrated that, when once established, this crop will thrive in more alkali than will serve to effectually prevent germination, or at least to destroy the young seedlings, it is doubtful whether the effort to secure a stand in such land without treatment for the purpose of neutralizing the effect of the salt is warranted. The sowing of alfalfa on poorly drained land often results in disappointment. This, however, is usually of no consequence on black sage lands, for the drainage here is usually good, and whatever failures occur on such soils are due more often to improper preparation of the land, resulting in inability to properly distribute the water. In such cases some portions receive too little water, while in others it is allowed to remain long enough to destroy the crop. The latter is especially likely to occur in the spring of the year, when the flood waters are abundant and there is a liability to desire to use them as much as possible. It is doubtful whether alfalfa can be grown to the best advantage on the lower bottoms, mainly on account of poor drainage. One or two fields planted in such localities were carefully studied, and from information received concerning them it was learned that the land needed reseeding much oftener than better-drained areas. The lower bottoms are much better adapted to growing redtop and timothy.

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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN No. 16.
B. T. GALLOWAY, Chief of Bureau.

A PRELIMINARY STUDY

OF THE

Germination of the Spores of Agaricus Campestris and other Basidiomycetous Fungi.

BY

MARGARET C. FERGUSON,

COOPERATING WITH

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 29, 1902.

Sir: I have the honor to transmit herewith a paper entitled A Preliminary Study of the Germination of the Spores of *Agaricus campestris* and other Basidiomycetous Fungi, and respectfully recommend that it be published as Bulletin No. 16 of the Bureau series. The paper was prepared by Dr. Margaret C. Ferguson at Cornell University, and was submitted by the Pathologist and Physiologist.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Recent investigations undertaken by Dr. B. M. Duggar, of this Office, show that there is a large and growing consumption of mushrooms for food in this country. As a rule the use of wild species of mushrooms is fairly safe where the collector knows which to take and which to avoid, but for the unskilled collector the cultivated product is much safer. This country imported last year about 3,000,000 pounds of canned mushrooms and practically all the spawn used, but there is no reason why we should not grow our own spawn and produce our own mushrooms. However, there are many difficult problems to be solved before the industry, which is comparatively new in this country, can be developed on the basis of accurate knowledge. The production of pure spawns of high vitality is one of the most important requirements, and should receive special attention. The accompanying paper is the result of work in this line undertaken and completed by Dr. Margaret C. Ferguson at Cornell University during the session of 1900–1901, under the direction of Dr. B. M. Duggar, then assistant professor of plant physiology in the university, and now a plant physiologist in this Office. Although technical, the paper bears directly on lines which are being developed in this Office, and will form the basis for future work having for its object the growing of pure virgin spawn. Work of this nature and its practical application are necessary for the better development of the mushroom industry in this country.

ALBERT F. WOODS,
Pathologist and Physiologist.

OFFICE OF THE PATHOLOGIST AND PHYSIOLOGIST,
Washington, D. C., January 29, 1902.

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A PRELIMINARY STUDY OF THE GERMINATION OF THE SPORES OF AGARICUS CAMPESTRIS AND OTHER BASIDIOMYCETOUS FUNGI.

INTRODUCTION.

During the past century many students have attempted, with varying degrees of success, to germinate the spores of the Basidiomycetous fungi. While some of these investigators have been able to germinate the spores of many of the Basidiomycetous fungi, their results with this group of plants have somehow failed to be of value in other departments of botanical research. The spores of the Basidiomycetes are seldom used to-day for cultural purposes. Neither have the successful experiments with edible forms become of widespread economic importance, for the French, who alone seem to have been successful in germinating the spores of the common edible mushroom, *Agaricus campestris*, keep their methods secret.

That the results of earlier investigators along this line have not received a wider application is probably due, in large measure, to the fact that they have treated this question almost exclusively from the standpoint of development and morphology. As will be seen from the history given at the close of this bulletin, the object of the student has been, as a rule, to germinate the spores that the life history of the plant might be studied. Thus the special conditions controlling germination in the Basidiomycetes have been almost totally neglected. In a recent paper by Duggar (1901), the question of spore germination has been considered in an entirely different way from that of the earlier investigators. His aim, as expressed in the introduction, was to determine in so far as possible the special factors which influence the germination of certain fungous spores.

It was for the purpose of learning somewhat more regarding the conditions under which germination occurs in the Basidiomycetes, and especially in *Agaricus campestris*, that this study was undertaken at the suggestion of Professor Duggar. The task has not proven an easy one, and after nine months of almost constant application much still remains to be done, although some results of considerable importance have been obtained. I regret, therefore, the necessity of publishing at this point, but circumstances are such as to render it impossible for me to continue the work further.

As already indicated, this study has been carried on under the direction of Prof. B. M. Duggar at the botanical laboratory, Cornell University, and it is with pleasure that I acknowledge my indebtedness to him for his many helpful suggestions and his constant and kind assistance.

METHODS.

It will be readily understood that it is difficult—almost impossible—to obtain basidiospores in an absolutely pure condition. By observing certain precautions, however, it is possible to get these spores in such a state of purity that contaminated cultures occur but rarely in sterilized media, and never in sufficient number to be a serious hindrance to the study of germination.

Before collecting material, Petri dishes were prepared for the reception of the spores. After these dishes were thoroughly cleaned, white paper was fitted into the bottom and a piece of absorbent cotton placed over the top of each dish. The cover dishes were put on and the cotton was trimmed off with scissors until it was even with the outer edge of the covers. The dishes were then sterilized in a dry oven and set aside for later use. If it happened that several days elapsed before these dishes were needed, they were again sterilized immediately prior to their use.

Sporophores were collected just as the veil was about to break, when one was present, and again when the pileus was fully expanded, or nearly so. Spores from fruit bodies which showed traces of disintegration were not found to be satisfactory. The sporophores were wrapped in tissue paper and taken at once to the culture room. The margin and outer covering of the pileus were removed with sterilized forceps and scalpel. The pileus was cut into thirds or fourths, and the pieces, separated from the stipe with the forceps, were inverted in the previously prepared Petri dishes. During this process the forceps and scalpel were repeatedly resterilized in a Bunsen flame. The time required for obtaining good spore-prints varied from four to twelve hours, depending on the species and on the maturity of the fruit bodies when collected. After removing the pilei, the Petri dishes were packed away in a cool, dark place. In this manner spores were kept in good condition for many months. With gelatinous forms the spores were obtained by washing the mass with sterilized distilled water, and then rubbing bits of this mass on sterilized cover glasses by means of a platinum needle. These cover glasses were stored in Petri dishes in the same manner as were the spore-prints, and when tested for germination a drop of the culture medium was placed directly upon the smeared part.

The hanging drop cultures, so generally used in such work, were found to be very satisfactory in this study. The methods employed in the use of the van Tieghem cell were such as have been described in detail by Clark (1899) and by Duggar (1901), and need not be repeated here. In a laboratory where several students are working upon physiological problems, the space in the thermostat which is available for each student often becomes much limited, and the question of economy in the use of that space comes to be a problem of considerable importance to the student. The writer has used a little device for supporting the slides which has proved to be very convenient. By means of it one can carry through a large number of cultures at once without making undue demands upon the thermostat. A description of this piece of apparatus is given in the appendix to this bulletin, with the thought that it may prove useful in general work.

The plant decoctions used as cultural media were made up according to the following formulas:

	Grams to one liter of water.
Green bean stems or pods	392
Sugar beets	370
Sporophores of *Calvatia cyathiforme*	300
Lepiota naucina (sporophores dried)	20
Pleurotus ostreatus (sporophores collected just after a rain)	400
Coprinus comatus, together with soil, grass, etc., in which it was growing	700
Fresh horse manure	85

A strong decoction of manure was also made from manure which had been fermented and was just ready to be used by the gardener in making up a mushroom bed.

The beef broth used was made after the formula ordinarily followed by bacteriologists.

The sugar solution was used at a concentration of $\frac{N}{10}$.

The distilled water employed in the experiments was always redistilled from a glass vessel and then sterilized.

Throughout the work the greatest care was taken to preserve the cultures free from contamination of any sort. Unless otherwise stated, the cultures were kept in a light-proof thermostat at a temperature of 28 ± C. For the sake of uniformity in making up the cultures for a given test, large numbers of spores were first transferred from the spore-prints to a drop of distilled water on a sterilized cover glass. The cover was kept inverted over one of the van Tieghem cells, to which it was fastened with vaseline, during the intervals when spores were not being transferred from the drop to the cultures. In this way, too, the danger of contamination by repeatedly opening the Petri dishes containing the spores was reduced to a minimum. I have used the number 99 to indicate perfect or almost perfect germination. The large numbers of spores sown in each culture made it impossible to be sure that every spore had germinated, and hence the number 100 will not appear in any of the tables which are given in this report.

EXPERIMENTAL.

SPORE GERMINATION (PRELIMINARY STUDY).

In order to determine the desirability of certain forms for cultural purposes, preliminary tests were made on the germination of the spores of a number of species including representatives of several families of the true Basidiomycetes.

The results of this preliminary work are given in Table I. Of all the species observed, the spores of *Polyporus brumalis* undergo the most marked changes during germination. These spores swell to several times their original size and become almost spherical in outline before putting out germ tubes. Usually two and frequently three tubes are protruded from each spore. With the first experiments observations were made sixteen hours after the spores were sown, and then, as a rule, twenty-four and forty-eight hours later; but the necessity for running the cultures for a longer time gradually became apparent. Thus it came about that the time at which the last examinations were made varied much throughout this earlier work and is given in each instance in the table. In every case the highest percentage of germination shown by either duplicate at the time of the last examination of the cultures is the percentage recorded.

By a study of Table I certain comparisons may be made with regard to the amount of germination on various media and at different temperatures. Most of the conclusions, however, which may be drawn are to be considered as provisional only. More than one-third of the species studied germinated in distilled water, though none of them showed perfect germination in this medium. Ninety per cent, that recorded for *Phlebia radiata* and *Hypholoma appendiculatum*, was the highest percentage of germination observed in distilled water. *Coprinus micaceus*, reported by Duggar (1901) as not germinating in distilled water, gave in these tests 60 per cent of germination. With the exception of *Merulius tremellosus* and *Pholiota* sp., every form which germinated in any medium gave more or less germination in distilled water. It would appear that an external food supply is necessary for germination in these two species, while in the other forms showing germination it is not necessary, though it certainly enhances the power of germination in these spores, as shown by the higher percentages obtained in nutrient media. Distilled water gave almost invariably somewhat better germination than tap water.

TABLE I.—*Percentage of germination.*

Spores of—	Time in hours of last reading at—		Culture media.													
			Distilled water.		Tap water.	Sugar solution.		Bean decoction.		Beet decoction.	Lepiota decoction.		Calvatia decoction.	Coprinus decoction.	
			Temperature.		Temperature.	Temperature.		Temperature.		Temperature.	Temperature.		Temperature.	Temperature.	
	28°±C	16°±C	28°±C	16°±C	28°±C	28°±C	16°±C	28°±C	16°±C	28°±C	28°±C	16°±C	28°±C	28°±C	16°±C
Coprinus micaceus	48	160	60	25	70	85	33	99	99	80	98	98	75	95	99
Hypholoma appendiculatum	48	160	90	0	75	85	0	99	99	90	98	99	99	95	99
Collybia velutipes	64	160	80	2	30	99	0	99	90	99	99	65	99	99	90
Lepiota naucina	92	160	50	0	0	75	0	99	0	90	50	0	85	99	0
Pleurotus ostreatus	48	160	50	25	2	15	30	98	10	95	75	40	45	50	50
Tricholoma personatum	92	160	50	.1	0	0	.1	99	.1	25	99	8	90	99	8
Armillaria mellea	64	160	10	10	.01	75	10	0	.5	25	30	1	5	50	10
Polyporus brumalis	48	160	50	10	.05	99	20	99	99	99	99	99	85	99	75
Phlebia radiata	64	160	90	80	0	99	75	99	99	99	0	90	99	99	99
Merulius tremellosus	64	160	0	0	0	0	0	90	75	95	75	50	95	99	30
Dacryomyces corticioides	48	160	10	3	0	(a)	10	75	0	(a)	50	0	10	10	0
Coprinus comatus	92	160	10	.5	5	0	0	0	5	0	5	5	0	0	4
Hypholoma sublateritium	48	160	0	10	0	0	2	40	85	0	10	50	10	40	90
Clitocybe candida	48	160	.01	2	.01	0	0	0	0	0	25	20	10	0	5
Pholiota	92	160	0	0	0	0	0	25	0	1	5	0	50	40	0
Coprinus atramentarius	64	160	0	0	0	0	.1	0	0	0	0	0	0	0	0
Agaricus campestris	92	160	0	0	0	0	0	0	0	0	0	0	0	0	0
Agaricus placomyces	92	160	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepiota cristata	64	160	0	0	0	0	0	0	0	0	0	0	0	0	0
Tricholoma terreum	92	160	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurotus sapidus	92	160	0	0	0	0	0	0	0	0	0	0	0	0	0
Pholiota squarrosoides	64	160	0	0	0	0	0	0	0	0	0	0	0	0	0
Calvatia cyathiforme	92	160	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycoperdon pyriforme	64	160	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycoperdon Wrightii	48	160	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycoperdon gemmatum	92	160	0	0	0	0	0	0	0	0	0	0	0	0	0

[a] One spore.

The inhibiting effects on germination of a temperature of 16° ± C. was much more marked in distilled water and sugar solution than in the other media. Heald (1898) has shown that in the case of fern spores an increase in temperature can be substituted for the stimulus of light, and it is evident from my experiments that in some of the Basidiomycetes a high temperature is the only special stimulus required to produce germination. It is rather significant that while *Hypholoma appendiculatum* gave 90 and 75 per cent germination at 28° ± C. in distilled water and sugar solution, respectively, there was no germination in these media at a temperature of 16° ± C. This test was repeated three times with duplicates, and in only one case was there any germination in these media at the lower temperature. In this instance 15 per cent of germination occurred after 164 hours in distilled water and 20 per cent in sugar solution. In the same tests all the other media gave almost perfect germination at both the higher and the lower temperature. The effect of a high temperature in the absence of all food, or when a carbohydrate alone is present, is certainly very marked in this case.

In all the forms which showed germination, with the exception of *Hypholoma sublateritium*, 16° C. is below the optimum temperature for germination. Germination was not only much retarded by this lower temperature, sometimes having been delayed for several days, but the final percentages were as a rule slightly lower. In many cases spores which had not germinated after having been kept at the lower temperature for one week germinated in twenty-four hours when transferred to the thermostat at 28° C. In the light of later results, there can be little doubt that some of the species, which gave no germination in these preliminary tests, would have germinated had the cultures been kept for a longer time.

For further study of the physiology of germination, *Agaricus campestris*, *Agaricus placomyces*, *Coprinus comatus*, *Lepiota naucina*, *Hypholoma appendiculatum*, *Polyporus brumalis*, *Merulius tremellosus*, *Phlebia radiata*, *Calvatia cyathiforme*, and *Lycoperdon pyriforme* were selected. This list includes species which had given almost perfect germination, others which had yielded various small percentages of germination, and still others which had been entirely resistant to the cultural conditions. With such a set of spores valuable results ought to be obtained regarding the stimulating or inhibiting effects of certain substances or conditions.

EXTREMES OF TEMPERATURE.

A large number of experiments were made with the fungi listed above to test the effects of extremes of temperature on their germination. This was suggested by the studies of Haberlandt (1878), Müller-Thurgau (1885), and Eriksson (1895). These investigators found that subjection to cold for a longer or shorter period not only improved the germinating power of certain seeds and spores, but affected favorably other life processes as well.

The spores to be tested were put into a few drops of distilled water in tiny vials which had been previously plugged with cotton and sterilized. Several sets of vials were made up and subjected to the following treatment before the spores were transferred to the cultures:

No. 1. Cold.[a]
No. 2. Cold + heat.[b]
No. 3. Cold + heat + cold.
No. 4. Heat.
No. 5. Heat + cold.
No. 6. Heat + cold + heat.

While the exposure to a high temperature was always for ten minutes, the spores were tested after having been in the cold for different lengths of time varying from one day to three weeks.

TABLE II.—*Percentage of germination after 168 hours.*

Temperature 28° ± C.

Spores of—	Spores subjected to—	Culture media.				
		Distilled water.	Sugar solution.	Bean decoction.	Lepiota decoction.	Coprinus decoction.
Hypholoma appendiculatum	A. Cold 1 day.	95	95	99	99	99
Polyporus brumalis		1	40	99	99,	99
Merulius tremellosus		0	0	....	....	....
Phlebia radiata		0	95	95	85	98
Lepiota naucina		0	25	50	10	15
Coprinus comatus		0	0	0	0	0
Agaricus campestris		0	0	0	0	0
Agaricus placomyces		0	0	0	0	0
Calvatia cyathiforme		0	0	0	0	0
Lycoperdon pyriforme		0	0	0	0	0
Hypholoma appendiculatum	B. Cold 6 days.	99	99	99	99	99
Polyporus brumalis		2	25	99	99	99
Merulius tremellosus		0	10	90	80	75
Phlebia radiata		50	50	99	75	99
Lepiota naucina		10	25	90	50	50
Coprinus comatus		0	0	0	0	0
Agaricus campestris		0	0	0	0	0
Agaricus placomyces		0	0	0	0	0
Calvatia cyathiforme		0	0	0	0	0
Lycoperdon pyriforme		0	0	0	0	0
Hypholoma appendiculatum	C. Heat.	95	95	99	99	99
Polyporus brumalis		25	30	99	99	99
Merulius tremellosus		10	5	90	98	85
Phlebia radiata		15	50	98	99	99
Lepiota naucina		15	50	99	99	95
Coprinus comatus		0	0	0	0	0
Agaricus campestris		0	0	0	0	0
Agaricus placomyces		0	0	0	0	0
Calvatia cyathiforme		0	0	0	0	0
Lycoperdon pyriforme		0	0	0	0	0
Hypholoma appendiculatum	D. Heat + cold 2 days.	90	98	99	99	99
Polyporus brumalis		5	99	99	99	99
Merulius tremellosus		25	95	99	99	99
Phlebia radiata		40	95	99	99	99
Lepiota naucina		40	90	98	98	98
Coprinus comatus		0	0	0	([c])	0
Agaricus campestris		0	0	0	0	5
Agaricus placomyces		0	0	0	0	0
Calvatia cyathiforme		0	0	0	0	0
Lycoperdon pyriforme		0	0	0	0	0

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[a] By "cold" it will be understood that the vials containing the spores were placed outside a north window in January. During the times of exposure the temperature ranged from 10° C. in the daytime to —5° C. at night. Usually, however, the temperature did not rise to more than 3° or 4° C. during the day.

[b] "Heat" indicates that the spores were heated to 42° C. in distilled water for ten minutes.

[c] 1 spore.

The records of the results obtained in the first four tests with extremes of temperature are to be found in the second table. This gives substantially all that there is to be learned from the whole series of temperature experiments. The spores were taken from the same spore print of each species in all four tests. By a comparison of these records certain conclusions seem evident. A longer exposure to cold is in most instances a better stimulus to germination than a shorter exposure; the deleterious effect of cold on germination is much more pronounced when no external food supply is present. To illustrate, it will be sufficient to compare the records made by two species at 28° C. as shown in Table I, and in sections A and B of Table II.

		Distilled water.	Bean decoction.
		Per cent.	*Per cent.*
Lepiota naucina	I	50	99
	II, A	0	50
	II, B	10	90
Phlebia radiata	I	90	99
	II, A	0	95
	II, B	50	99

A short exposure to a high temperature seems to be a stimulus to germination, but heat followed by cold acts as a slightly stronger stimulant. It will be noted that the spores of *Merulius tremellosus* did not germinate in distilled water until after having been subjected to a temperature of 42° for ten minutes, and that the spores of *Agaricus campestris* first germinated under the combined action of heat and cold. It does not appear, however, after a study of several hundred cultures in which the spores had been subjected to extremes of temperature, that such treatment is of any marked advantage in the germination of the spores of *Agaricus campestris.*

It was found that heating in water at 52° C. for ten minutes was sufficient to kill the spores, at least of those forms which had germinated under other conditions. Also, repeated freezings and thawings in water during a period of three months destroyed the vitality of the spores. Later on in the work spores of *Agaricus campestris* were several times put into distilled water and submitted to the action of a freezing mixture, temperature—18° C., for from ten to twenty minutes. Only in very rare instances did such spores germinate after being transferred to the culture media. Frequently the spores lost their characteristic appearance and showed undoubted evidence of having been injured by the extreme cold.

ACTION OF AN ARTIFICIAL DIGESTIVE FLUID.

It is well known that *Agaricus campestris* occurs naturally in stable yards and in pastures, and it is generally supposed that the spores germinate in these situations after having passed through the digestive tract of herbivorous animals. Janczewski (1871) was able to prepare the spores of *Ascobolus furfuraceus* for germination only by feeding them to rabbits, and it was suggested by Professor Duggar that the action of an artificial digestive fluid might have the same effect. Spores of *Agaricus campestris*, *Coprinus comatus*, and *Calvatia cyathiforme* were used in these tests.

Five-tenths and one-tenth per cent solutions of pepsin in distilled water were combined with hydrochloric acid at a concentration of $\frac{N}{100}$, $\frac{N}{1000}$, and $\frac{N}{10000}$, also in distilled water. A few drops of each concentration were put into vials, spores were added, and the vials after being sealed were placed in the thermostat. After 24 hours, at the end of 3 days, and again after 7 days, spores were transferred to culture drops of distilled water, and of decoctions of manure, Coprinus, and bean pods. The experiments were repeated three times with four duplicates each time, and the cultures were kept for 8 days. *Calvatia cyathiforme* and *Coprinus comatus* showed no germination. Several of the cultures of *Agaricus campestris* gave various small percentages of germination; but no germination occurred in distilled water nor in the larger number of the other cultures. One culture in Coprinus decoction registered 25 per cent, the highest percentage of germination which had been observed in *Agaricus campestris* up to that time. The spores of this culture had been treated with $\frac{N}{10000}$ HCl and one-tenth per cent solution of pepsin for 7 days before they were transferred to the hanging drop. But in the three duplicate cultures, and in fact in all the other cultures of this experiment, not a single spore was observed to germinate. With the other two experiments frequently from 10 to 20 per cent of the spores of one of the four duplicate cultures germinated; in other instances two, three, and occasionally all four of the duplicate cultures showed some germination. Such irregularities are not peculiar to the tests with an artificial digestive fluid, but are characteristic of nearly all the experiments made with the spores of *Agaricus campestris*. I am wholly unable to account for these erratic results. It would seem that the state of maturity or other conditions of the spores must be the cause; but that other factors are also influential in producing them there can be little doubt in the light of later experiments. On the whole, there was somewhat more germination in the cultures containing $\frac{N}{1000}$ and $\frac{N}{10000}$ HCl than with those with $\frac{N}{100}$ HCl; but it seemed a matter of indifference whether one-half or one-tenth per cent of the pepsin was present.

Temperature tests as previously described were combined with the action of this artificial digestive fluid, but the amount of germination was not thereby appreciably increased. Germination occurred in a greater number of cultures with this treatment, but the percentages rarely exceeded 12. Other experiments were made in which the hydrochloric acid and pepsin were put directly into the various media used in the cultures. The results were not substantially different from those obtained by subjecting the spores to the combined action of hydrochloric acid and pepsin for different lengths of time, and then transferring them to drops of pure decoction.

EFFECT OF ACIDS ON GERMINATION.

Hoffman (1860) found that weak acids did not exercise a stimulating effect upon the germination of Basidiomycetous spores. And inasmuch as the experiments with hydrochloric acid and pepsin had given only small percentages of germination, it was thought that the acid might have an inhibiting action on these spores. We therefore tried the effect of this acid on spores that were known to germinate abundantly in media not acid. The results are recorded in Table III.

The conditions governing germination in *Agaricus campestris* seemed so complex and subtle that the other species were dropped at this point, and the investigations thenceforth were directed almost entirely to the problems of germination in this economic species.

Experiments with malic, lactic, and hippuric acids were repeated several times. The results given in Table IV are fairly typical. There was never any germination in malic acid, but both lactic and hippuric acids gave small percentages of germination—now in one medium, now in another. Spores which had been heated in $\frac{N}{1000}$ HCl and one-half per cent pepsin in distilled water, and then exposed to outside temperatures from January 5 to January 29, were transferred to cultures of manure and Coprinus decoctions containing hippuric acid. Positive results were obtained in 10 out of 14 cultures in 168 hours. This was the most uniform germination that had yet been obtained with *Agaricus campestris*, but in no case did the percentage of germination exceed 15.

TABLE III.—*Percentage of germination after 1 day.*

[Temperature 28 ± C.]

Spores of—	HCl in Lepiota decoction.				
	$\frac{N}{300}$ HCl.	$\frac{N}{500}$ HCl.	$\frac{N}{1000}$ HCl.	$\frac{N}{5000}$ HCl.	$\frac{N}{10000}$ HCl.
Coprinus micaceus	25	25	20	50	70
Hypholoma appendiculatum	95	98	97	97	98

Table IV.—*Percentage of germination after 10 days.*

AGARICUS CAMPESTRIS.

Temperature 28 ± C.

Medium.	4 drops of N malic acid[a] in—					
	2 cc. of decoction.	4 cc. of decoction.	6 cc. of decoction.	8 cc. of decoction.	10 cc. of decoction.	12 cc. of decoction.
Coprinus decoction	0	0	0	0	0	0
Bean decoction	0	0	0	0	0	0

Medium.	4 drops of N lactic acid[a] in—					
	2 cc. of decoction.	4 cc. of decoction.	6 cc. of decoction.	8 cc. of decoction.	10 cc. of decoction.	12 cc. of decoction.
Coprinus decoction	0	20	[b]1.5	[c]2	[d]5	0
Bean decoction	0	0	0	0	0	0

Medium.	10 drops of a saturated solution of hippuric acid[a] in—					
	2 cc. of decoction.	4 cc. of decoction.	6 cc. of decoction.	8 cc. of decoction.	10 cc. of decoction.	12 cc. of decoction.
Coprinus decoction	0	0	0	0	0	0
Bean decoction	0	0	0	0	10	8

[a] The decoctions were neutralized before the acids were added.
[b] 75 spores. [c] 95 spores. [d] 250 + spores had germinated.

ACIDS FOLLOWED BY ALKALIES.

After six days the spores which had not germinated in the acid cultures were, in many cases, transferred to cultures of similar decoctions containing varying percentages of ammonium hydrate, sodium carbonate, and potassium hydrate, respectively. These gave only negative results, as did also the experiments in which fresh spores were put into several different concentrations of the above named acids in distilled water, and subjected to extremes of temperature before being sown in alkaline media.

EFFECT OF LIGHT ON GERMINATION.

Spores were sown in cultures of various media, and in the presence of all the different stimuli which had yielded germination in the dark in any culture throughout this entire study. One set of these was placed in direct sunlight and another in diffuse light. After 4 weeks no germination had occurred in any of the cultures. This would seem to indicate that light has an inhibitory effect on the germination of these spores; but the point needs further investigation.

AGE OF THE SPORES RELATIVE TO THEIR POWER OF GERMINATION.

No exhaustive study has been made regarding the effect of age on the germination of the spores of *Agaricus campestris*. But incidentally it has been demonstrated that the spores will germinate if placed in cultures on the same day in which the spore-prints have been obtained. Spores 6 months old have also been brought to germination, but spores older than this have not been tested. We are, therefore, unable to say during how long a period these spores may retain their vitality. The results obtained in this study show very conclusively, however, that, other things being equal, the comparatively fresh spores are much more satisfactory for cultural purposes than are the older ones.

A NEW FACTOR IN GERMINATION.

During the greater part of this work it was my practice to discard cultures after from 200 to 240 hours. As a rule, observations were made at the end of 72, 96, 144, 168, and 240 hours, respectively. If germination occurred at all it usually appeared in about 7 days, but in a few cases 4 days sufficed. This was followed by a rapid growth; but no signs of further germination being apparent at the close of 10 days, there seemed no reason why these cultures should not be replaced by other experiments. The spores from those cultures in which partial germination had occurred were transferred at this time to test tubes of sterilized manure, bean stems, and other solid substrata.

At one time in the early spring, after 250 cultures had been running for the usual number of days, it was felt that it might be well to keep them for a longer time. They were again examined after 336 hours when, to my great surprise, I found almost perfect germination in some of the cultures. This set of cultures was kept for 4 weeks and examined 11 times, but there was no apparent change after 384 hours. A few of the results obtained are given in Table V. In the light of these observations, all previous work seemed to require repetition. By way of comparison, some of the results from an experiment of about 500 cultures which followed the test referred to above are given in Table VI. The spores in the first 2 cultures in each decoction, and in each concentration of the particular stimulus used (Table V), were from a spore-print 55 days old. The last 2 cultures in every instance in Table V contained spores which had been obtained but 7 days prior to being sown. Spores from this same spore-print were used in the first 2 cultures of every medium in Table VI, but were sown more than a month later. The other cultures in this last experiment contained spores from a spore-print but 12 days old.

We would not have it understood from these tables that in just 9 days after sowing, some spores germinated, and that on the twenty-first day 95 per cent, more or less, of germination occurred. Some spores had emitted germ tubes after 4 days, others after 7, and still others not until the end of 14 days. Hence "9 days" is used as an average time for the first appearance of germination. The "21 days" gives the results as recorded at the last examination of the cultures. The cultures were examined 11 times, but it would not be well to complicate these tables by reporting all the readings. In every case where a high percentage of germination has finally occurred it has been preceded a few days by the germination of 1 or more spores. The germ tubes of the first spores germinating are very broad (Pl. I, fig. 1), and, if conditions are favorable for their growth, they develop rapidly, ramifying in every direction (Pl. I, fig. 6). From 5 to 10 days later almost every spore in such cultures germinates, forming 1 or 2 short, almost spherical tubes (Pl. I, fig. 2). It has never happened in these cultures that 40 per cent of the spores germinate, then 75 per cent, and later 99 per cent; but after the hyphae from a few spores of *Agaricus campestris* have developed to a greater or less degree, all other spores in the culture may send out germ tubes, if not simultaneously, certainly at about the same time. In some cases it has happened that a single spore has germinated at one side of the culture and grown toward the mass of spores collected at the center of the drop. Just as it has reached this mass nearly every spore, as by magic, has emitted a germ tube.

The germination of a few spores does not insure fuller germination under all circumstances. Some spores have germinated in several cultures containing asparagin, but these have shown little growth, and never any further germination; the same phenomenon has been observed in many cultures and various media. But I have never seen anything like perfect germination which has not been preceded by a considerable growth, in the culture, of the mycelium of *Agaricus campestris*.

Attention is called to the fact that in the presence of ammonium nitrate 60 per cent of the spores finally germinated in one culture in distilled water (Table VI). This is the highest percentage of germination observed for *Agaricus campestris* in distilled water in the presence of any stimulus tested. In this instance there was considerable growth from the 2 spores which germinated first, hence the fuller germination. Whether the ammonium nitrate was sufficient of itself to nourish for a time the growing hyphae, or whether in its presence the organic substance of some of the other spores became available as food, remains an open question. That the spores contain within themselves sufficient food for the first stages of growth following germination seems doubtful in view of the fact that when a large number of spores germinate in a given culture there is no further growth unless the spores are transferred to drops of fresh decoction.

The erratic results characteristic of all the cultures of *Agaricus campestris* are well illustrated by the records given in Tables V and VI. In the check, 1 culture of the 4 duplicates in each decoction yielded over 90 per cent germination, and the other 3 gave absolutely none. In the first experiment 12 cultures with ammonium hydrate registered a percentage of from 80 to 99, and not a single spore in lactic acid germinated. But in the second test exactly the opposite was true. No germination occurred in the presence of ammonium, while there was more than 90 per cent germination in several of the cultures with lactic acid.

TABLE V.—*Percentage of germination.*

Temperature 28°± C.

AGARICUS CAMPESTRIS.

Culture media.	Check.		NH_4OH						KOH					
			$\frac{N}{100}$		$\frac{N}{1000}$		$\frac{N}{10000}$		$\frac{N}{100}$		$\frac{N}{1000}$		$\frac{N}{10000}$	
	9 days.	21 days.	9 days.	21 days.	9 days.	21 days.	9 days.	21 days.	9 days.	21 days.	9 days.	21 days.	9 days.	21 days.
Bean decoction	0	0	0	0	0	0	3 spores	90	0	0	0	[a]35	0	0
	0	0	0	0	3 spores	98	1 spore	0	0	0	0	0	0	0
	1 spore	98	0	10	1 spore	80	0	....	0	0	0	0	0	0
	0	0	1 spore	98	0	0	2 spores	2 spores	0	1 spore	0	0	0	0
Beet decoction	0	0	0	0	6 spores	50	0	0	0	0	0	0	0	0
	0	0	0	0	1 spore	....	2 spores	80	0	0	0	0	0	0
	0	0	1 spore	2 spores	0	0	0	0	0	0	2 spores	98	0	0
	1 spore	90	0	0	0	0	11 spores	99	0	0	0	0	0	0
Manure decoction	0	0	2 spores	99	7 spores	85	1 spore	99	0	2 spores	0	0	0	0
	0	0	1 spore	2 spores	3 spores	....	0	1 spore	0	0	0	0	2 spores	55
	0	0	7 spores	99	0	0	2 spores	95	1 spore	1 spore	0	0	0	0
	1 spore	99	2 spores	2 spores	4 spores	90	2 spores	80	0	0	0	0	0	0
	—17° for 10 min.		Lactic acid.						Hippuric acid.					
Bean decoction	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beet decoction	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manure decoction	0	0	0	0	0	0	0	0	10 spores	40	0	0	0	0
	0	0	0	0	0	0	0	0	3 spores	4	0	0	0	0
	0	0	0	0	0	0	0	0	....	0	0	0	0	0
	0	0	0	0	0	0	0	0	120 spores + 3 per cent.	0	0	0	0	0

[a] Four days after a few germinated spores from another culture had been transferred to this culture.

TABLE VI.—*Percentage of germination.*

Temperature 28° ± C.

AGARICUS CAMPESTRIS.

Strength of solution.	NH_4OH in—								NH_4NO_3 in—							
	Distilled water.		Bean decoction.		Manure decoction.		Lepiota decoction.		Distilled water.		Bean decoction.		Manure decoction.		Lepiota decoction.	
	9 days.	21 days.	9 days.	21 days.	9 days.	21 days.	9 days.	21 days.	9 days.	21 days.	9 days.	21 days.	9 days.	21 days.	9 days.	21 days.
$\frac{N}{100}$	0	0	0	0	....	....	....	....	....	....	1 spore	98	....	....	....	....
	0	0	0	0	....	....	....	....	....	....	0	0	....	....	....	....
	0	0	0	0	....	....	....	....	....	....	4 spores	50	....	....	....	....
	0	0	0	0	....	....	....	....	....	....	0	0	....	....	....	....
$\frac{N}{1000}$	0	0	0	0	0	0	....	....	0	0	0	0	0	0	....	....
	0	0	0	0	0	0	....	....	0	0	0	0	0	0	....	....
	0	0	0	0	0	0	....	....	0	0	0	0	0	0	....	....
	0	0	0	0	0	0	....	....	0	0	0	0	1 spore	1 spore	....	....
$\frac{N}{10000}$	0	0	0	0	0	0	0	0	2 spores	60	0	0	0	0	7 spores	7 spores
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3 spores	95
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4 spores	25
	0	0	0	0	0	0	0	0	0	0	0	0	5 spores	5 spores	0	0
	Lactic acid.								Asparagin.							
$\frac{N}{100}$	....	....	15 spores	100 spores + 1.5 per cent.	....	....	....	....	....	....	0	0	....	....	....	....
	....	....	0	0	....	....	....	....	....	....	0	0	....	....	....	....
	....	....	0	0	....	....	....	....	....	....	0	0	....	....	....	....
	....	....	0	0	....	....	....	....	....	....	0	7 spores	....	....	....	....
$\frac{N}{1000}$	50 spores +	50 spores +	100 spores +	99	0	0	....	....	3 spores	5 spores	1 spore	2 spores	0	0	....	....
	100 spores +	800 spores + = 2 per cent.	33 spores	98	28 spores	98	....	....	0	0	0	0	0	0	....	....
	0	0	0	3 spores	4 spores	4 spores	....	....	0	0	0	0	0	0	....	....
	0	0	0	3 spores	2 spores	98	....	....	2 spores	5 spores	2 spores	2 spores	0	0	....	....
$\frac{N}{10000}$	5 spores	5 spores	11 spores	95	0	0	45 spores	95	0	0	2 spores	3 spores	0	0	3 spores	3 spores
	100 spores +	500 spores + = 1 per cent.	18 spores	99	3 spores	3 spores	23 spores	40	0	1 spore	0	0	0	0	0	0
	0	0	2 spores	10 spores	1 spore	1 spore	3 spores	99	0	0	0	0	0	0	5 spores	5 spores
	0	0	0	1 spore	0	0	9 spores	75	0	0	3 spores	3 spores	0	0	3 spores	3 spores

I can suggest no entirely satisfactory explanation of these variations. The utmost care was taken, not only to avoid organic contamination, but, also, in the use of pure chemicals and clean dishes. A sufficient amount of each medium was made up at the beginning of the work to last throughout the year, and a given medium was not stored in one large flask, but in several small ones to avoid change by repeated sterilizations. It seems impossible, therefore, to account for the erratic results by impurities or variations in the culture media. And to say that the cause lies wholly in the spores is equally unsatisfactory. When making up the cultures for a given test, the spores, as described earlier, were thoroughly mixed in a drop of distilled water before being transferred to the hanging drops. Under such conditions it seems extremely improbable that all the spores transferred to one medium should be incapable of further development, while large numbers of those transferred to another medium should be capable of germination. But after all it can not be doubted that an important factor in this problem is to be found in the condition of the spores themselves.

In this connection it has been observed that the spores from one spore-print have given more uniform germination than those from any of the many other spore-prints tested. In this case the fungus was raised in the conservatory of the Department by Mr. Shore, and the large, beautiful sporophore was taken immediately after the pileus had expanded. Large numbers of spores have been sown in each culture from the first; for, only small percentages of germination having been obtained, it was thought that the condition of maturity of the spores might largely control results. And in case no spores capable of germination were sown, one might conclude that the special stimulus tested had inhibited germination. The massing of the spores had no stimulating effect, as spores scattered through the drop germinated quite as frequently as those massed at the center. It is probable that the irregularities thus far recorded were due, in some measure, to the fact that up to this point in our study we had not found the best stimulus for the germination of these spores.

EFFECT OF MYCELIUM ON GERMINATION.

Mention has been made of transferring the spores from cultures which had germinated to a solid substratum in test tubes. In some cases, especially on bean stems, an abundant growth of mycelium resulted, and was available for the study of the effect of the mycelium on germination. The results of these experiments were very conclusive, as is shown by a glance at Table VII. This table records the readings for a single decoction, but many other decoctions were used with similar results. Where there was no mycelium present a few spores germinated in some cultures after 240 hours, perfect germination occurring only after 384 hours, but cultures into which bits of the mycelium had been introduced gave almost perfect germination in 144 hours. In some decoctions containing a bit of the mycelium germination did not occur until after 168 hours. In all cases the presence of the growing mycelium caused a high percentage of germination at least one week sooner than it might otherwise have occurred, that is, by the germination of a few spores the mycelium of which would act as a stimulus.

TABLE VII.—*Percentage of germination.*

Temperature 28° ± C.

AGARICUS CAMPESTRIS.

Culture media.	Hours.						
	96	144	168	240	312	384	504
Manure decoction	0	0	0	0	0	0	0
	0	0	0	0	0	0	0
	0	0	0	3 spores.	3 spores.	99	99
	0	0	0	0	0	0	0
Manure decoction, with a bit of the mycelium of Agaricus campestris	0	98	98	98	98	98	98
	0	95	95	95	95	95	95

In no cultures in which the growing mycelium of *Agaricus campestris* has not been present has a high percentage of germination ever occurred in any of the tests made in connection with this study. It is very evident that the growing mycelium in some manner prepares the way for germination. As to just how this is done it is, perhaps, vain to conjecture at present, but it is not improbable that some secretion is formed which stimulates or makes possible the emission of the germ tubes. Hartig (1894) has found that the presence of ammonium or some other alkali is necessary for the dissolving of the "spore pellicle" before germination can take place in *Merulius lachrymans.*

De Bary (1884) stated that the necessity of oxygen for the germination of fungous spores has never been sufficiently demonstrated; and it was thought that the phenomenon under discussion might be due to the fact that the great majority of these spores were able to germinate only after the oxygen of the hanging drop had been exhausted. We have not been able to test this point experimentally; but, if the presence or absence of oxygen were the controlling agent here, it would seem that the growth of the mycelium of any other fungus would affect germination as favorably as that of *Agaricus campestris* itself. This, however, is not the case, as mentioned later.

It has been determined, then, beyond a question, *that if a few spores are able to germinate under the cultural conditions, or if a bit of the mycelium of Agaricus campestris be introduced into the culture, the growth resulting will in either case cause or make possible the germination of nearly all the spores of the culture, provided, of course, that the other conditions are not such as to inhibit germination.* Mycelium that is not growing, or masses of spores, have not been observed to influence germination. Tests with the growing mycelium of Mucor, Penicillium, *Coprinus micaceus*, and *Hypholoma appendiculatum* have yielded only negative results. In one culture, however, with the mycelium of *Hypholoma appendiculatum* about 50 per cent germination occurred, but there is a possibility that in this instance one or more spores of *Agaricus campestris* germinated first and were obscured from view by the mycelium which had been introduced into the culture. The presence of the mycelium of these forms does not inhibit germination, for if a few spores emit germ tubes in the cultures with them, the fuller germination follows in due time, as when no foreign fungus is present. Spores of *Coprinus micaceus* and *Hypholoma appendiculatum* were sown in cultures with the spores of *Agaricus campestris*. They germinated after a few hours and grew abundantly, but at the end of three weeks the spores of *Agaricus campestris* had given no evidence of germination.

The effect of the presence of the growing mycelium of *Agaricus campestris* on the spores of *Agaricus placomyces* and *Calvatia cyathiforme* was also tested. After several weeks there was not the least sign of germination in any of the cultures.

The germ tubes which are emitted under the influence of the growing mycelium of *Agaricus campestris* are short, thick, and, as a rule, almost spherical in outline (Pl. I, fig. 2). Little or no growth has ever been observed to follow this later germination, even when the cultures have been kept for several weeks. But if these spores are transferred to fresh media, growth begins at once. (Pl. I, figs. 3 and 4.)

A list of substances tested with regard to their effect on the germination of the spores of Agaricus campestris.

THOSE YIELDING POSITIVE RESULTS, OR, AT LEAST, OCCASIONALLY YIELDING POSITIVE RESULTS.

Distilled water.

Bean decoction.

Beet decoction.

Lepiota decoction.

Calvatia decoction.

Decoction of *Coprinus comatus* together with the soil in which the fungi were growing.

Decoction of fermented stable manure.

Decoction of fresh horse manure.

Lactic acid in distilled water, and in decoctions of bean, beet, Coprinus, Lepiota, and manure.

Hippuric acid in decoctions of bean, manure, and Coprinus.

Hydrochloric acid + pepsin in distilled water, and in bean, Coprinus, and manure decoctions.

Hydrochloric acid + pepsin + hippuric acid in distilled water, and in decoctions of bean, Coprinus, and manure.

Ammonium in bean, beet, and manure decoctions.

Potassium hydrate in bean, beet, and manure decoctions.

Ammonium nitrate in distilled water, and in decoctions of bean, Lepiota, and manure.

Potassium nitrate in bean and manure decoctions.

Asparagin in distilled water, and in bean, Lepiota, and manure decoctions.

Mycelium of *Agaricus campestris* in distilled water, and in decoctions of bean, beet, Lepiota, Coprinus, beef, and manure.

Bean agar.

Manure agar.

SUBSTANCES YIELDING NEGATIVE RESULTS.

Sugar solution.

Beef decoction.

Pleurotus decoction.

Glycerin.

Malic acid in Coprinus and bean decoctions.

Hippuric acid in distilled water and in beet decoction.

Hydrochloric acid + pepsin in Lepiota decoction.

Hydrochloric acid + pepsin + hippuric acid in Lepiota decoction.

Malic acid followed by potassium hydrate in bean, Coprinus, and manure decoctions.

Malic acid followed by ammonium in bean, Coprinus, and manure decoctions.

Malic acid followed by sodium carbonate in bean, Coprinus, and manure decoctions.

Lactic acid, followed by potassium hydrate in bean, Coprinus, and manure decoctions.

Lactic acid followed by ammonium in bean, Coprinus, and manure decoctions.

Lactic acid followed by sodium carbonate in bean, Coprinus, and manure decoctions.

Malic acid followed by hydrochloric acid + pepsin in bean, Coprinus, and manure decoctions.

Lactic acid followed by hydrochloric acid + pepsin in bean, Coprinus, and manure decoctions.

Alcohol in bean, beet, and manure decoctions.

Ether in bean, beet, and manure decoctions.

Ammonia in distilled water and in Lepiota decoction.

Potassium hydrate in distilled water and in Lepiota decoction.

Potassium nitrate in distilled water and in Lepiota decoction.

Potassium sulphate in distilled water and in Lepiota and bean decoctions.

Potassium carbonate in distilled water and in decoctions of bean, Lepiota, and manure.

Sodium sulphate in distilled water and in decoctions of bean, Lepiota, and manure.

Spores sown between cover glass and filter paper moistened with bean, beet, Coprinus, and manure decoctions.

Spores subjected to pressure by being placed in drops of manure, and of Lepiota decoction between larger cover glasses.

Mycelium of Mucor in distilled water, and in bean, beet, Coprinus, Lepiota, Lycoperdon, and manure decoctions.

Mycelium of Penicillium, as for Mucor.

Mycelium of *Coprinus micaceus* in Lepiota and manure decoctions.

Mycelium of *Hypholoma appendiculatum* in Lepiota and manure (?) decoctions.

Germinating spores of *Coprinus micaceus* in Lepiota and manure decoctions..

Germinating spores of *Hypholoma appendiculatum* in Lepiota and manure decoctions.

A high percentage of germination has, perhaps, been more frequently obtained with cultures in pure Lepiota decoction than in any other decoction used. Of the chemical stimuli tested, ammonium compounds and lactic acid seem to be the most effective.

It must not be inferred when no germination has occurred in a given medium or in the presence of certain stimuli that these substances necessarily have an inhibitory action. They may have, but because of the very erratic nature of the results thus far obtained a much more extended study of this subject must be made before the fact of such inhibition can be definitely established, for, although between 4,000 and 5,000 cultures have already been made, we are not yet in a position to draw final conclusions. This would not be considered a large number of cultures if one were working with the molds where tests can be carried through in three days, or in less time. But when studying a form which must be kept in culture for three weeks, and repeatedly examined, it becomes a much more arduous task. When cultures require to be kept for a long time, frequent readings may not seem necessary; but it is much more satisfactory not to allow too long a period to elapse between the examinations of the cultures. In fact, because of contaminations and other irregularities that may appear in such cultures, frequent observations are absolutely necessary if results are to be reliable.

So far as the writer is aware there is recorded here the highest percentage of germination yet observed in *Agaricus campestris.* Judging from Repin's (1898) statement, "The spores which germinate, and these are always the fewest in number, * * * " the French have not obtained anything like perfect germination, and no record has been found of the germination of these spores by other students.

The results which we have obtained would seem to indicate that the problems involved here must be very complex and subtle. And while this study throws much light on the questions at issue, it can be considered as scarcely more than preliminary to the work which must follow before the secrets which *Agaricus campestris* has guarded so closely through the ages are revealed. Professor Duggar has already made arrangements for carrying on this work, not only to determine definitely the conditions controlling germination, but with a view to the practical application of the same in mushroom culture.

CONDITIONS OF GROWTH.

Incidental to the other work, and as opportunity offered, a few experiments have been made regarding the conditions of growth in some of the Basidiomycetes.

Hypholoma appendiculatum and *Coprinus micaceus* have been found to lend themselves with the greatest ease to artificial cultural conditions. There is no difficulty at all in obtaining pure cultures of these forms by the ordinary methods of preparing dilution cultures. Their spores have never failed to germinate in any agar in which they have been sown. They germinate in from six to twelve hours and grow rapidly. The spores nine months old germinate quite as rapidly as when first gathered. Little time has been devoted to the germination of the spores of *Collybia velutipes;* but from the few experiments which have been made I believe that this is another form which may be of value for cultural purposes. Heretofore, students occupied with the physiological problems of nutrition, osmotic pressures, toxicity, etc., have worked either with the algae, or with the lower fungi. There is no reason, whatever, why these studies should not be extended to include such Basidiomycetous forms as those named in this paragraph.

COPRINUS MICACEUS.

Transfers of *Coprinus micaceus* have been made from pure cultures to sterilized test tubes containing bean pods, bean stems, sugar-beet plugs, pieces of decayed wood, wheat straw in bean decoction, and wheat straw in manure decoction. Abundant growth has resulted in every case with the exception of the sugar beet. The writer has rarely succeeded in obtaining good growth with any Basidiomycete on the sugar beet as a solid substratum, although almost perfect germination occurs in a decoction of the beet.

To further test the growth of this fungus, sand was put into ordinary glass fruit jars to the depth of an inch and a half, and water was added until it stood a little above the sand. Two or three dead hickory boughs were placed in each jar, and the covers put on, the rubbers being left off to admit air. A thick piece of absorbent cotton was then tied over the top of each, and the jars sterilized. Other jars were filled to the height of 3 or 4 inches with chopped wheat straw, to which a little water was added, and a small vessel of water was placed in each jar to insure a moist atmosphere. These were covered and sterilized as described above. After some mycelium had been transferred from test tubes to these jars, the glass covers and absorbent cotton were immediately replaced. Under these conditions the mycelium grew luxuriantly; and in every instance it showed the same structure, and also the same beautiful amber or burnt orange color which have been found to be characteristic of a certain mycelium growing on the posts and other pieces of timber in mines. The sporophores of *Coprinus micaceus* have been observed in connection with this mycelium in the mines; but, if I am correctly informed, a connection between the two has never been definitely established. There can be no doubt, in the light of our cultures, that the two are united, and that this deep yellow mycelium is the characteristic mycelium of *Coprinus micaceus*.

About three weeks after these cultures were started, some sterilized sand was poured into the jars containing chopped straw, and in a few days numerous small sporophores appeared. These did not reach full development under sterile conditions, but some of them expanded at once when the absorbent cotton and the covers were removed and an abundance of free air admitted. Some porous pots were partly filled with sand and decayed wood, others with soil and decayed wood, and sterilized. These were inoculated with the mycelium of *Coprinus micaceus* and put in a warm, moist place in the conservatory. In about three weeks sporophores appeared.

HYPHOLOMA APPENDICULATUM.

The mycelium of *Hypholoma appendiculatum* has also been found to grow vigorously in test tubes containing bean pods or stems, and on sterilized wheat straw in manure and in bean decoctions, but it has shown little or no growth on sugar-beet plugs. It developed a splendid growth of mycelium in fruit jars of sterilized straw, but no sporophores were formed.

AGARICUS CAMPESTRIS.

Considering the results obtained with the action of an artificial digestive fluid, it seemed very desirable to test the effect on the spores of *Agaricus campestris* of a passage through the animal body. Some large glass jars were partly filled with horse manure, others with chopped wheat straw, and thoroughly sterilized. After a rabbit had been kept in captivity for some days and fed only on carefully washed vegetables he was given a quantity of these spores. The gills of the fungus were wrapped in carefully washed lettuce leaves or mixed with sterilized bran and water. When the rabbit had been fed for several days on this diet alone, the animal excrement obtained on the last day was placed in the previously prepared glass vessels and sterilized sand was then added to the depth of 1¼ inches. The jars were placed under suitable conditions of light and temperature, but after having been kept for several months they yielded only negative results. The excrement of the rabbit was also put into large test tubes containing sterilized stable manure. These, too, gave no positive results. In every one of the cultures, however, species of the Coprini appeared. The most abundant form developed was probably *Coprinus solstistialis*, but it was not determined to be such with certainty.

The spores of *Agaricus campestris* which had germinated in drop cultures were frequently transferred, as already mentioned, to test tubes containing sterilized manure, wheat straw in manure decoction, wheat straw in bean decoction, bean pods, bean stems, sugar-beet plugs, manure agar and bean agar, respectively. In the test tubes containing manure there was never any further growth. This is surprising considering the natural habitat of this fungus, and can be explained only on the supposition that the manure was not obtained under proper conditions, although great care was exercised in its selection, and tests were made both with the fresh horse manure, and with manure which had been fermented by the gardener preparatory to making a mushroom bed. On the other hand, there was a considerable development of mycelium in the slant tubes of manure agar, and also on the wheat straw in manure decoction. This suggests that the manure may have been used in too concentrated a form.

In one test tube containing sugar-beet cylinders, there was an abundant growth of mycelium; but as a rule little development occurred on this substratum, and there was rarely any growth unless the spores had germinated in a drop of beet decoction. Of all the solid substrata used, bean stems gave invariably the best results. Photographs of two such cultures are reproduced in Pl. II. In every instance in which germinated spores were transferred to bean stems, growth resulted, irrespective of the medium in which the spores had germinated.

HISTORICAL.

According to Hoffman (1859), the germination of fungous spores was first studied by Prevost (1807) and Ehrenberg (1821). Since their publications, especially during the latter half of the past century, various investigators have occupied themselves with a study of the germination of the spores of the fungi. Inasmuch as the accounts of this work have, so far as I am aware, never been brought together, there is to-day, in the minds of students in general, a rather indefinite idea as to the present status of this study, particularly with reference to the Basidiomycetes. In view of this fact it becomes desirable to give at this time a brief summary of the results already obtained along this line.

This review will be confined exclusively to a consideration of the literature which deals with the phenomenon of germination as exhibited in the Basidiomycetes. Frequently the reports of this work do not form separate papers, and the results obtained can be determined only after diligently searching through long treatises. No attempt is made in the present paper to give an exhaustive treatment of this history; but it is doubtful if any important references have been omitted. Such empirical cultures of the Basidiomycetes as have been carried on in Italy and in other parts of the world from a very early date have recently been described somewhat in detail by Constantin (1892), and will not be considered here.

1842. Corda made the statement that the spores of the fungi germinate just as readily as do all seeds and the spores of many higher plants; but he gave no proof of this experimentally. In the same year, however, he figured in his Icones Fungorum the germinated spores of *Sphærobolus stellatus.* He did not germinate these spores by artificial means, but sketched them in the condition in which he found them where they had been scattered from the sporangia.

1853. Tulasne described and figured the germination, in water or moist air, of the spores of *Tremella mesenterica* Retx., *Exidia spiculosa* Sommerf., *Tremella violacea* Reth., and *Dacryomyces deliquescens* Dub.

1855. Sachs studied the development of *Crucibulum vulgare*, but did not observe the germination of the spores, and said that such germination had not been obtained in artificial cultures in the Nidulariaceæ.

1859. Hoffmann published an account of his germination, in water and in moist air, of the spores of several Basidiomycetes. He discussed briefly, and illustrated the first stages in the development of the following species: *Dacryomyces deliquescens* Dub., *Lycoperdon constellatum* Fr., *L. verrucosum* Ruff. (*L. gemmatum* Batsch.), *Bovista plumbea* Pers., *Cyathus striatus*, *Tremella mesenterica* Retz., *Spathula fluvida* Fr., *Thelephora quercina* Pers., *T. uvida* Fr., *Hydnum auriscalpium* L., *Trametes suaveolens* F., *Agaricus Coprinus plicatilis* Curt., and *Agaricus velutipes* Curt. He found that the spores of Lycoperdon germinated with difficulty, their germination being the exception rather than the rule.

1860. Hoffmann continued his investigations along this line, considering to some degree the physiology of the process. He seems to have been the first to have studied to any extent the germination of Basidiomycetous spores under definite and known conditions. His experiments were so conducted that the germinating spores could easily be studied under the microscope without disturbing the cultures, but there is no evidence that any special precautions were observed to keep the cultures free from contamination. He made many temperature tests, and also studied the effects of light and various chemicals, chiefly acids, on germination. It was found that the time of year did not matter for germination, but that the spores required only the proper moisture and temperature; germination seemed to be as good in direct or diffused light as in darkness, but the spores of *Agaricus campestris* germinated earlier in the dark than in the light; spores not germinated were not killed by frost, though freezing was found to be fatal to germinated spores; spores in a state of germination were actually killed by drying, but many spores germinated better in moist air than in water; no evidence was found that weak acids favored germination, and it was concluded that a period of rest was not necessary for the germination of Basidiomycetous spores, though many of them germinated after a period of weeks and even years. He determined the length of time required for germination, and sketched the germinated spores of *Polyporus versicolor* (5 days), *P. sqwamosus* (6 days), *Coprinus micaceus* (1 day), *Psathyra stypticus* (3 days), *Mycena vulgaris* (2 days), *Collybia Oreades* (3 days), *C. conigenses* (3 days), *Coprinarius papilionaceus*, *Thelephora hirsuta*, and *Exidia* (*Tremella*) *grandulosa*. In this later work he was unable to germinate the spores of Lycoperdon.

1861. La Bourdette, in a note regarding his methods of culture, claimed that after several years of experimentation he had succeeded in developing the edible Agaricus from spores by means of potassium nitrate and without the use of manure. The nitrate was put into the soil with the spores of the agaric to the depth of from 3 to 4 mm. The soil was composed largely of calcium sulphate beaten down and nothing added. Under these conditions an indefinite growth of the fungus was obtained. According to his statements, the mushrooms derived by the method just described attained an average weight of 600 grams, while those obtained by the ordinary complicated methods of culture averaged but 100 grams.

1861. Chevreul presented to the Academy of Science, Paris, some mushrooms that had been grown by La Bourdette. La Bourdette had sown the spores in sand and water on a glass plate. The most vigorous plants thus obtained were later transferred to a humid soil composed of vegetable earth. This soil was placed in a cave and covered with sand and river gravel to a depth of .25 m., this being again covered with broken plaster .15 m. in depth. The bed was watered with water containing 2 grams of potassium nitrate to a square meter of the soil. Under these conditions the fine group of sporophores sent to the academy had developed in six days.

These results seem to have been accepted with a grain of salt, as it were, even by some of La Bourdette's contemporaries.

1863. Nylander found something of the fabulous in La Bourdette's reports, and believed that his fungi had come up by chance, having no connection whatever with the spores that had been sown. He had never himself been able to germinate the spores of *Agaricus campestris* in cultures, and had found no evidence in literature of such germination. He cultured these spores many months in hot, moist chambers, and on different substrata, but chiefly on horse manure, and never saw even the beginnings of germination.

The gills of *Agaricus campestris,* and the water in which the fungi had been washed when prepared for food, were scattered in places where this fungus often chanced to come up, but they never produced the plant. This was repeated for many years, but always with negative results. He thought it a matter of great interest to determine the method of germination of these spores and the physiology of the process, and he suggested that by an easy experiment, but one of great weight, it might be shown whether the spores of *Agaricus campestris* require, before they will germinate, to be subjected to such a digestive process as that which takes place in the animal intestines.

1865. De Bary referred to the germination of *Coprinus fimetarius* which produced mycelium and fruit in a proper nutrient medium, and also spoke of the germination of the spores of the Tremellineæ and of Dacryomyces.

1866. De Bary reported much work done on the germination of the Phycomycetes and Ascomycetes, and figured such germination; but he seems to have attempted at this time the germination of only one Basidiomycete, *Phallus impudicus,* and to have failed in this.

1867. Woronin, according to De Bary, germinated the spores of *Exobasidium vaccinii,* and determined the length of a generation to be fourteen days under the most favorable conditions; that is, on the leaves of Vaccinium.

1870. Pitra, twenty-eight years after Corda had recorded his observations on germination in *Sphaerobolus stellatus,* found the germinated spores of this species in the sporangium and figured them. He observed nothing peculiar in this germination, and noted that the hyphæ might grow from one or both ends of the spore.

1872. Woronin determined that the spores of *Coprinus ephemerus* would germinate in six hours in a thoroughly cooked and filtered decoction of horse manure.

1874. Hartig, as reported by De Bary, described in full the development of *Agaricus melleus.*

1875. Eidam demonstrated the easy germination, in drops of manure decoction, of the spores of all the Coprini which he had studied. Spores of *Agaricus coprophilus* germinated in from eighteen to twenty hours and conducted themselves exactly like those of the Coprini. He made the interesting observation that in spite of like conditions not all of these spores germinated at the same time. In some cases germination did not take place until after four days, and then short, thick tubes were put out.

1875 and **1876.** Van Tieghem who, like Eidam, was seeking to demonstrate the presence of sexual organs in the Basidiomycetes succeeded in germinating the spores of several Coprini, *Agaricus coprophilus, Hypholoma fascicularis, Pholiota mutabilis, Galera tener, Collybia velutipes,* and many forms with white spores. The stages of development could be easily traced in all, but showed most beautifully in *Collybia velutipes.*

1876. Hesse published a paper on the germination of the spores of *Cyathus striatus.* He did not accept Hoffman's germination of the spores of this species, and said that now, sixteen years after the appearance of Hoffman's report, there was recorded for the first time the real germination of this form. Spores were collected at various times of the year, and cultures made in water, in nutrient solution, and on sterilized rabbit manure, but no germination occurred. The same methods were tried with *Geaster*, *Bovista*, *Lycoperdon*, *Tulostoma*, *Scleroderma*, etc., but with these, also, they resulted in failure. It was thought that the spores of the Gasteromycetes might first be capable of germination after passing through the animal body, and experiments to determine this point were tried, but gave only negative results.

At last he succeeded in bringing the spores of *Cyathus striatus* to germination; but he did not wish to describe his methods until he had convinced himself that he had found not only the way to germinate these spores, but the spores of other Gasteromycetes as well. This much, however, he ventured to reveal, that these spores would germinate in pure water in from eighteen to twenty-four hours if the other necessary conditions for germination had been fulfilled.

1876. Eidam's publication, in which the germination of the spores of *Cyathus striatus* and *Crucibulum vulgare* was described and figured, appeared almost simultaneously with Hesse's paper. Eidam considered that the negative results obtained by the earlier students of these species were due to the fact that the spores had not been brought into conditions favorable for their germination and further development prior to the setting up of the cultures. In order to eliminate this source of error the spores were placed in suitable nutriment under a bell jar lined with moist blotting paper and kept at a temperature from 20–25° C. for a day and a night. Thus the life activity of the spores was enhanced. Those kept at the room temperature from October to December gave results much more slowly and quite irregularly.

Decoctions of plums or prunes, bark, decaying wood, hay, and horse manure, filtered and crystal clear, were used as culture media. Due precautions were exercised to obtain the spores in as pure a condition as possible. The spores of *Cyathus striatus* germinated in a decoction of manure at a temperature of about 25° C. One, two, or three germ-tubes were formed. The spores were also germinated and abundant mycelium developed on sterilized horse manure. Several germ tubes were developed from each spore in *Crucibulum vulgare*, and the spores swelled to twice their normal size before emitting tubes.

1876. Reese added his name to the list of those who had germinated the spores of the Coprini. He affirmed that he had tried in vain to get positive results with *Agaricus campestris*, *Sphærobolus stellatus*, and *Crucibulum vulgare*, and that he had at last turned to *Coprinus stercorarius*. This species germinated in from four to five hours in a sterilized decoction of horse manure; and, in the presence of a high temperature and much moisture, fruit bodies were formed in eight days. If kept cooler and drier the length of a generation was from eighteen to twenty days. Fruit bodies of *Coprinus ephemerus* were never obtained in less than twenty-four days after the germination of the spores.

1877. Brefeld's first important work on the Basidiomycetes appeared, as is well known, in 1877. He succeeded at this time in obtaining the early stages of development for a considerable number of species.

Spores of *Coprinus stercorarius*, *C. ephemerus*, *C. ephemeroides*, and *C. lagopus* germinated easily and surely in a decoction of manure. Sporophores of *Agaricus melleus* were placed in a watch glass for a quarter of an hour. Some of the spores thus obtained were transferred to a drop of fruit decoction, where they germinated in three days. According to his investigations, the spores of the Nidulariaceæ germinated readily at a temperature of 15 to 18°. *Typhula variabilis* and *T. complanata* were studied, and their spores germinated as representatives of the Clavariaceæ. The spores of *Tremella* were easily and surely germinated, but only when freshly thrown off. In the case of *Dacryomyces deliquescens,* the spores germinated, after several divisions, with conidia formation. Conidia were formed in all the species studied, but only those of Tremella were observed to germinate. Many Geasters and Lycoperdons were cultured, but the spores of none of them were brought to germination.

1881. Brefeld has given a detailed account of his culture methods in the fourth part of his studies of the Fungi. It would not be practicable to enter upon a discussion of those methods here. They are familiar to all students of mycology at the present day. We might, however, remark, in passing, that he used a great variety of decoctions, and evidently employed sterilization precautions wherever possible throughout his work.

1884. De Bary gave a partial summary in 1884 of the results obtained previous to that time in the germination of Basidiomycetous spores, but he contributed little to the subject that was really new. He considered the external conditions necessary for the germination of fungous spores to be a supply of water, a supply of oxygen, a certain temperature, and in some cases a nutrient substance or food supply. He made the statement later, however, that the necessity of oxygen for the germination of these spores had never been sufficiently tested. Of the fungi whose basidiospores had never been certainly known to germinate he cited *Agaricus campestris,* the Lycoperdaceæ, Phalloideæ, and Hymenogastreæ.

1884. Fischer studied the life history of *Sphærobolus stellatus.* Very beautiful cultures were obtained by sowing sporangia on sawdust that had been boiled in water and afterwards put into porous clay dishes. After the sporangia were sown the pots were set into water that the cultures might be kept moist. As many as six fruit-bodies, measuring from 9 to 9½ cm., were developed in a single pot at one time. Spores kept from the end of February to the following October germinated, but more slowly than fresh spores.

Gemmæ and basidiospores were found inside the same sporangium, and the germination of both was observed and figured. For a long time he was not able to induce the spores to germinate. High temperatures, feeding to birds, etc., were tried, but always with negative results. He had almost come to the conclusion that these spores were not capable of further development when they were found to germinate in less than twenty-four hours in a culture of manure decoction free of gemmæ. Each spore was observed to emit a single germ-tube, whereas Pitra (1870) found tubes at both poles of the spores. For this reason Fischer thought that Pitra did not see the basidiospores germinate, but the gemmæ instead, as these send out hyphæ from both ends. He also doubted that Corda (1842) saw these spores germinate. Many of the spores do not germinate, but gradually disintegrate; and he suggests that in this species the gemmæ have assumed the function of the spores, and produce mycelium at the cost of the true basidiospores which are used to nourish the growing hyphæ.

1888 and **1889.** Brefeld published parts seven and eight of his studies of the Fungi in 1888 and 1889, respectively. These volumes are devoted almost exclusively to a consideration of the development of the Basidiomycetes. In them the author describes the germination of more than one hundred and sixty species, and mentions over forty others which were cultured but failed to germinate. The very interesting discovery was made that while the spores of *Panæolus campanulata* germinated only in manure decoction, the mycelium grew abundantly in all the nutrient solutions in which the spores would not germinate. This was also said to be true for the Coprini, and for almost all the manure-inhabiting Agarics.

1891. Constantin germinated the spores of *Nyctalis lycoperdoides* in pure cultures on all sorts of nutrient substances—oak and beech leaves, potato in orange juice, beet, carrot, and on other mushrooms. The spores germinated in twenty-four hours at a temperature of 24°, and later gave rise to normal fruit-bodies. He was able to keep cultures of this species for three years without contamination.

Marasmius oleæ was also cultured. Olive leaves covered with small plants were put on a plate and placed under a bell-jar. When the fruit-bodies appeared, he placed sterilized watch glasses, containing sterilized water under the caps. Basidiospores were thus gathered and transferred by means of a platinum needle to test-tubes containing sterilized olive leaves. After some time, sporopores of the *Marasmius* appeared in these tubes.

1892. Scholz was able to trace every step in the development of *Agaricus melleus*, and, according to his reviewer, he observed much that was new.

1894. Hartig demonstrated the fact that the spores of *Merulius lachrymans* germinate, in cultures, only when ammonia or the salts of sodium or potassium are added to the infusion in which the spores are placed. He did not believe that these salts were to be regarded as nutritive in their effect, but that they merely served to render possible the removal of the spore pellicle that covers the germ aperature. He was of the opinion that every spore and every seed contains a certain quantity of nourishment derived from the parent plant, and instantly available for use in germination· hence an external supply of food can not be necessary.

1894. Constantin's paper on the culture of *Polyporus squamosus* can be mentioned only by title, as the writer has been able to obtain neither the original article nor any review of it.

1895. Wehmer brought some frozen specimens of *Pleurotus ostreatus* into the laboratory after about two weeks of continued frost. The plants were gradually thawed out, and the spores collected. Somewhat later these spores were found to germinate abundantly in sugar solution.

1898. Repin published a bulletin which contains this statement (quoted from a reprint in English): "There is no mystery in the germination of mushroom spores. It can be brought about on any of the nutrient media used by bacteriologists, but germination does not take place with rapidity, and requires to be stimulated by some artificial means or contrivances, which vary with the ideas of the operator, and which may be discovered after some fruitless experiments have been made " This lucid statement can not be said to contribute greatly to our knowledge of the subject in hand.

Judging from Repin's sentence, "The spores that will germinate, and these are always the fewest in number, do so by—," it would appear that the students of the Pasteur Institute had not succeeded in obtaining a high degree of germination with the spores of *Agaricus campestris.*

1901. Duggar, in his recent investigations of the germination of fungous spores, studied but four Basidiomycetes—*Coprinus micaceus, C. comatus, C. fimetarius,* and one species of *Boletus.* Of these, *Coprinus comatus* and *Boletus* showed no germination; *Coprinus fimetarius* gave small percentages of germination in plant decoctions only; and *Coprinus micaceus* gave almost perfect germination in bean and dung decoctions, but scarcely any germination in solutions devoid of plant decoction. The mycelium of *Coprinus micaceus* was found to grow abundantly in solutions in which the spores failed to germinate. The conclusion was therefore drawn that, if the stimulus to germination be a food stimulus, it must belong to the class of peculiar foods.

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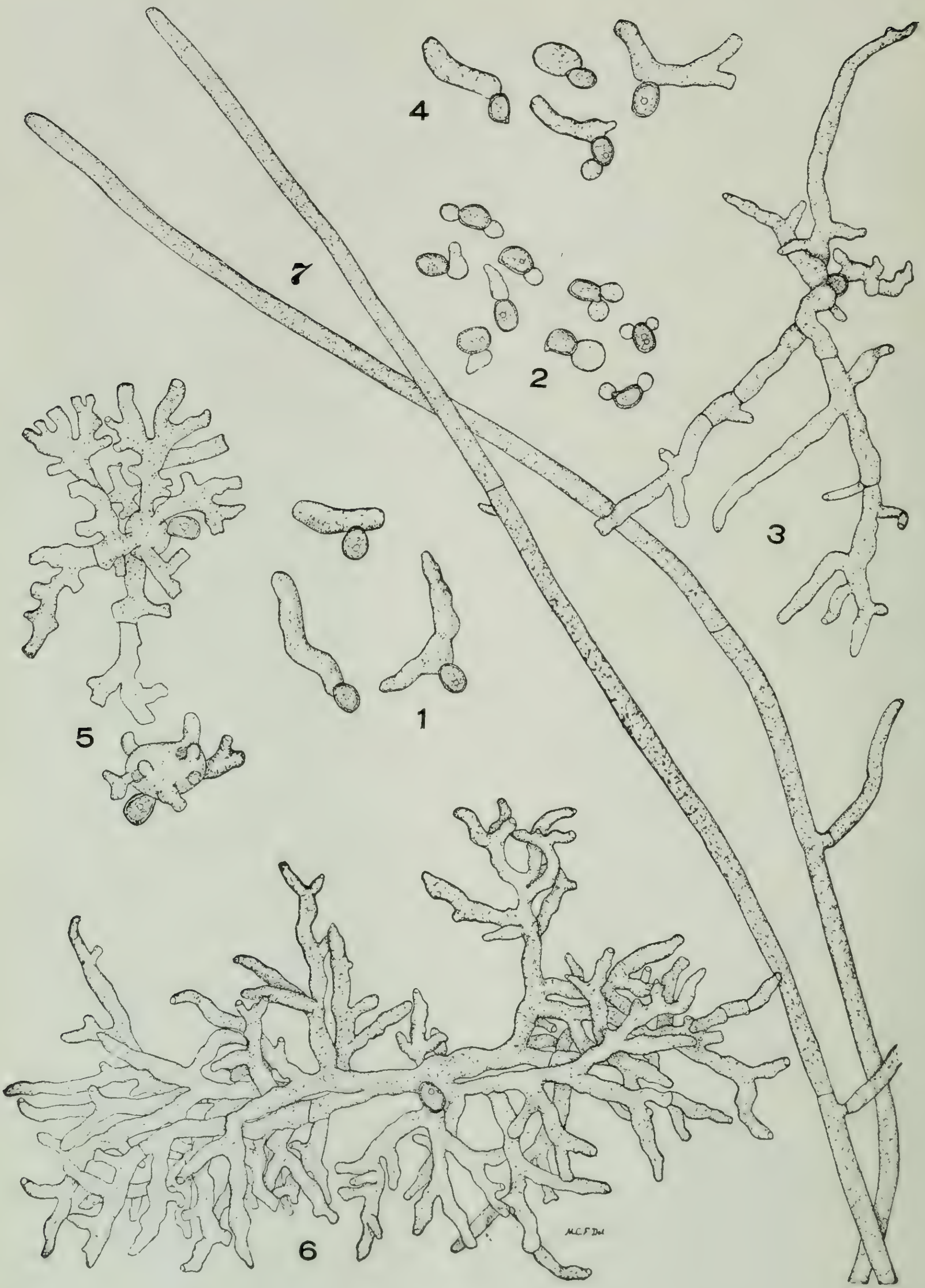
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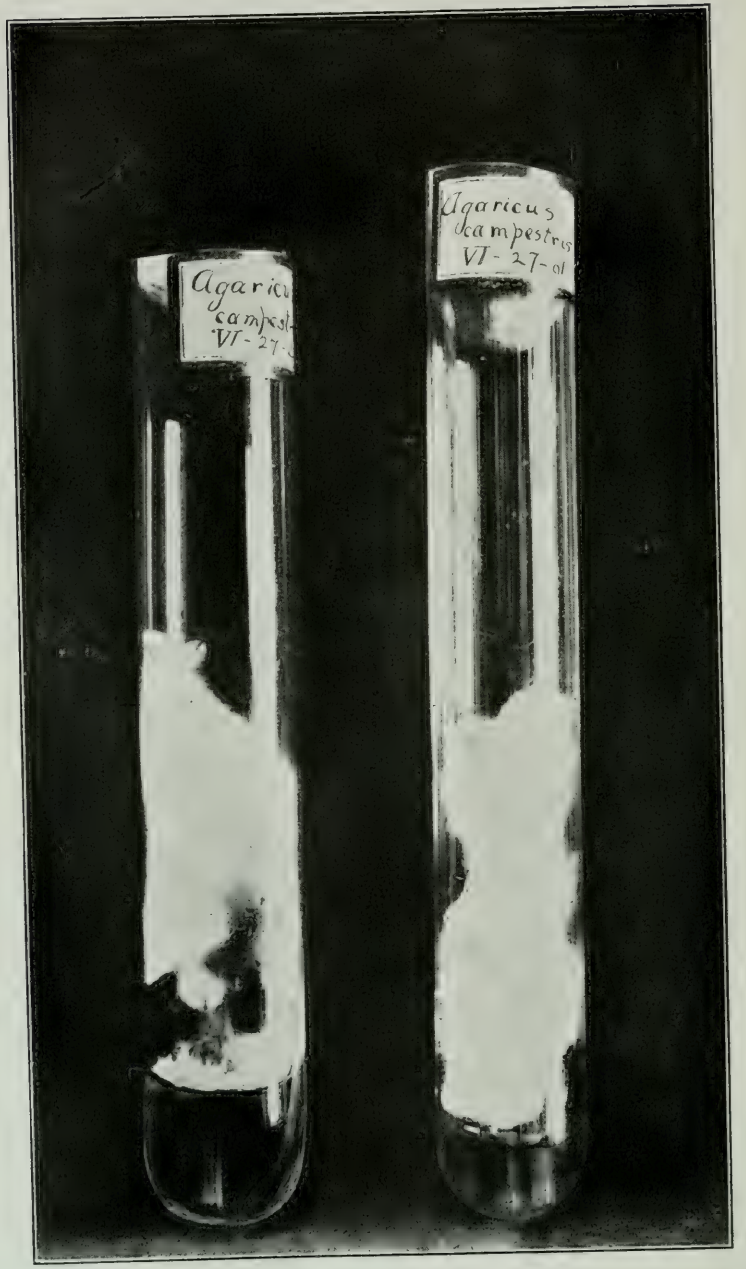
AGARICUS CAMPESTRIS, GERMINATED SPORES.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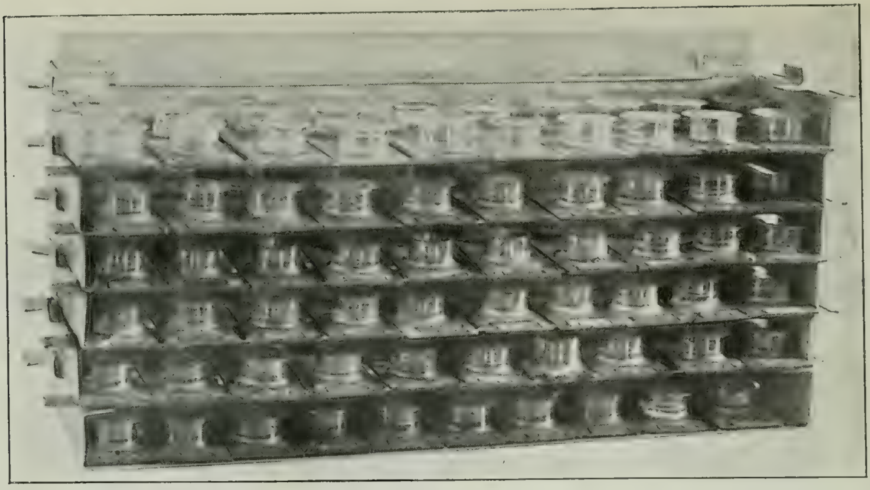
MYCELIUM OF AGARICUS CAMPESTRIS.

Some spores were germinated in a hanging drop and then transferred to bean stems in test tubes. The photograph was taken by Dr. B. M. Duggar ten days after the spores had been transferred to the tubes.



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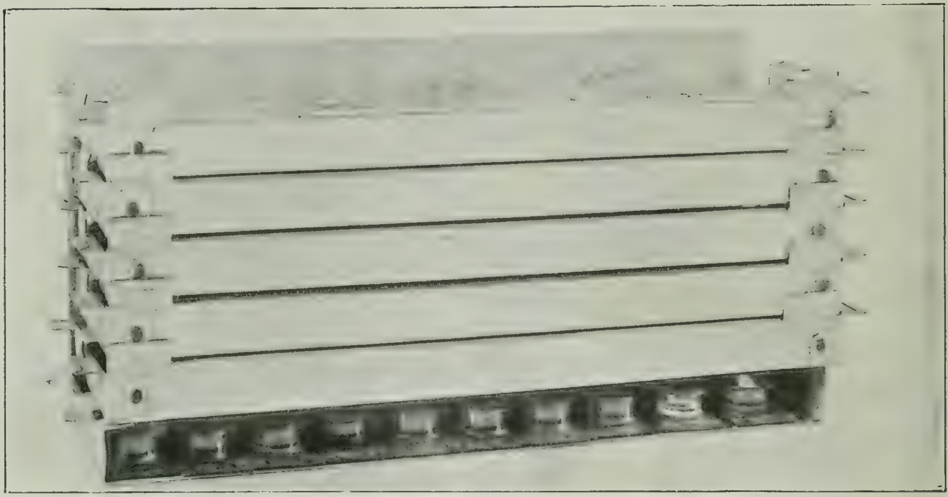

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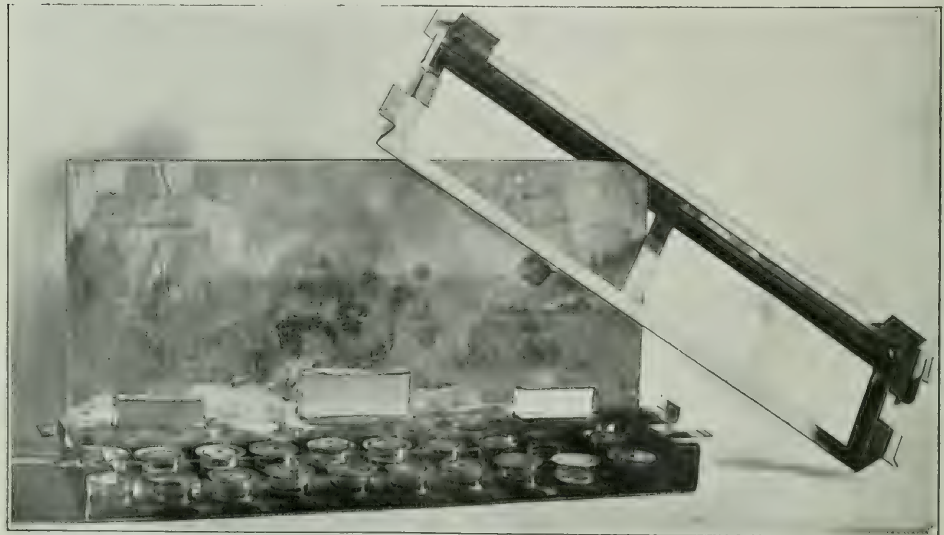

Bottom tray and one of the other trays.

STAND FOR SUPPORTING VAN TIEGHEM CELLS.

EXPLANATION OF PLATES.

PLATE I.—AGARICUS CAMPESTRIS.

Fig 1. The germinated spores as they appear when but a few spores have germinated in a given culture. In bean decoction.

Fig. 2. The germinated spores as they appear when large numbers of spores germinate under the influence of the growing mycelium of Agaricus campestris. These spores had been kept for a week after their germination, but showed no evidence whatever of further growth. In Lepiota decoction.

Fig. 3. One of the spores shown in fig. 2, twenty-four hours after it had been transferred to a drop of fresh Lepiota decoction.

Fig. 4. Some spores which had germinated in manure decoction, showing exactly the same appearance as those in fig. 2. They were kept for one week after germination, but showed no signs of further development, and were then transferred to a drop of fresh manure decoction. They were figured twenty-four hours after the transfers were made. It will be noted that growth was much slower than in the Lepiota decoction. (Fig. 3.)

Fig. 5. Germination and growth in manure decoction containing hippuric acid.

Fig. 6. A germinating spore showing the irregular, much-branched hyphæ characteristic of the first stages of growth. In beet decoction.

Fig. 7. The outer ends of two threads showing the characteristic structure of the older mycelium. In Lepiota decoction.

PLATE II.—MYCELIUM OF AGARICUS CAMPESTRIS.

Spores germinated in a hanging drop, and then transferred to bean stems in test-tubes.

PLATE III.—A STAND FOR SUPPORTING THE VAN TIEGHEM CELLS.

Fig. 1. The stand open, as when one is examining the cultures.

Fig. 2. The stand closed and ready for placing in the thermostat.

Fig. 3. The bottom tray and one of the other trays, showing structure.

APPENDIX.

A CONVENIENT STAND FOR HOLDING SLIDES IN CELL-CULTURE WORK.

A stand for supporting the slides, when one is using the Van Tieghem cells, should be made of such material and in such a way that it will neither burn, warp, nor melt upon being heated, for it is often desirable to sterilize the cells before making up the cultures. It should also combine economy of space with ease of manipulation. All these points are characteristic of the little piece of apparatus which I have used, three views of which are shown in Plate III.

This stand consists, as will be seen from the illustrations, of a series of trays placed one above another. Each tray was made from a single piece of tin without the use of solder. The tin measured 13¼ by 3⅞ inches after the edges were turned. This was folded on three sides, just as one folds a piece of paper in making the boxes described by Lee (1896) for embedding material in paraffin. A strip 1⅛ inches wide along both ends and on one side was bent up at right angles to the rest, so that a box, open at the top and along one side, was formed, which measured 11 by 2¾ inches on the bottom. The double, triangular, ear-like projections formed at the two corners were folded along the back and secured by means of rivets. The tin was then cut or slashed three-eighths of an inch deep 1 inch distant from either corner on the back. Similar cuts were also made at the corners, and three, equally distant from each other and from the outer edges, were made on either end. The segment of tin along the middle of the back and those next to the free, outer segments on the ends were folded in until parallel with the bottom. These act as a shelf on which to rest the next higher tray. The outer and innermost segments at both ends were bent outward, forming projections which are very useful in lifting the trays. The second segment from the corner on either end was bent out at right angles to the side, and then the outer portion of it was again turned up until it was parallel with the position which it formerly occupied. These, with the segments at both corners along the back, which were left erect, prevent the next higher tray from slipping or sliding. It was found desirable to cut the bottoms of the trays out, as shown in fig. 3, since the rapid absorption of heat by the tin has a tendency to increase the condensation moisture on the cover glasses.

For convenience in use, it is necessary that the trays be about one-fourth of an inch narrower than the slides are long. Unfortunately the slides thus extending over the edges of the pans are very easily struck, and the cultures thereby endangered when one is putting other material into or taking it out from the thermostat. To guard against such accident, as well as for greater ease in carrying, a bottom tray was made one-fourth of an inch wider than the others, and with a back 5½ inches high. This tray had five segments cut at each end, instead of four, and these were turned the same as in the other trays except that the outermost was bent in to give greater stability. Shelves were made along the back by cutting and folding in the tin at three points (fig. 3). The windows thus formed give free circulation of air. These windows, each 2½ inches long and 1 inch deep, were so cut that if the pieces of tin freed along three sides had been bent straight inward, they would have formed shelves one-fourth of an inch higher than those at the ends. But they were doubled in close against the back for one-fourth of an inch, and then turned out until they stood parallel with the bottom of the tray. This gives a little back at the points where the windows occur and prevents any cultures on the second tray from slipping through these open spaces. For convenience in handling, the bottom was not cut from this first tray as from the others, and it may be used as a support for cultures or not, at the discretion of the investigator.

The trays were all made of the same size. Five trays besides the bottom one constitute "a set" as we have used them. Each set holds 120 cultures and occupies only 36 square inches of space in the thermostat. The trays may, of course, be made of any length or of any height, the dimensions given being those best suited to the thermostat which we have used. When all the trays have been filled in making up a set of cultures (fig. 1), the five upper ones are lifted together and so placed on the lowest pan that their open sides are against the back of this tray (fig. 2).

The number of words which seem to be necessary for accurately describing this little piece of apparatus makes it appear somewhat complicated; but if one will take a piece of paper of suitable dimensions and follow the description given, he will find that the making of a model for one of these trays is a very simple matter.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN No. 17.

B. T. GALLOWAY, Chief of Bureau.

SOME DISEASES OF THE COWPEA.

I. THE WILT DISEASE OF THE COWPEA AND ITS CONTROL.
By W. A. Orton, *Assistant Pathologist.*

II. A COWPEA RESISTANT TO ROOT KNOT (Heterodera radicicola).
By Herbert J. Webber, *Physiologist,* and W. A. Orton, *Assistant Pathologist.*

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

PATHOLOGICAL AND PLANT BREEDING LABORATORIES.

Issued April 22, 1902.

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1902.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief.
Washington, D. C., January 20, 1902.

Sir: I have the honor to transmit herewith two papers, one entitled The Wilt Disease of the Cowpea and its Control and the other A Cowpea Resistant to Root Knot, and respectfully recommend that they be published as Bulletin No. 17 of the Bureau series, under the general title Some Diseases of the Cowpea. The papers were prepared, respectively, by Mr. William A. Orton and Mr. H. J. Webber, both of Vegetable Pathological and Physiological Investigations, and were submitted by the Pathologist and Physiologist.

Respectfully,
B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Among the diseases of plants most difficult to deal with are those which attack the roots. For a number of years this office has been investigating such diseases and has published several bulletins in regard to them. Among these diseases is the wilt of cotton, which spread so rapidly over many valuable cotton areas as to render cotton growing impossible on the infected soil. Mr. William A. Orton, the author of the first paper of this bulletin, was sent to South Carolina in 1899 to inaugurate a series of investigations with a view of finding a means of controlling this wilt. He found, as a result of the first year's work, that it would be impracticable to destroy the fungus by any method of treating the soil. In the course of his investigations, however, his attention was called to the fact that certain plants were resistant to the wilt, and by selecting such plants he obtained a number of strains of the best varieties sufficiently resistant to the disease to be grown on the worst infected lands.

The first part of the present bulletin deals with a disease of cowpeas closely related to the wilt disease of cotton. This is so prevalent in certain areas as to render the growth of the cowpea, which is one of the most valuable rotation crops, impossible in such areas. Working on the principle of the resistance of certain plants, as in the case of cotton, a variety of cowpea, known as the Iron, which is resistant to the disease, has been found, and no doubt other resistant varieties will be obtained. The second part of the bulletin deals with the so-called eel worm, or root nematode. This attacks the roots of the cowpea and causes them to swell and become distorted, thus preventing normal healthy growth. The ordinary varieties are peculiarly sensitive to this trouble, and as the same eel worms attack many other crops there is danger of these becoming infested where the cowpea is used as a rotation crop.

Albert F. Woods,
Pathologist and Physiologist.

Office of the Pathologist and Physiologist,
Washington, D. C., January 20, 1902.

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SOME DISEASES OF THE COWPEA.

I. THE WILT DISEASE OF THE COWPEA AND ITS CONTROL.

By W. A. ORTON, *Assistant Pathologist.*

INTRODUCTION.

The investigation of the wilt disease of the cowpea was undertaken by the writer in connection with similar work on the wilt of cotton and watermelons, begun in 1899. These diseases had previously been studied by Dr. Erwin F. Smith, of this Department, and in Bulletin No. 17[1] of the Division of Vegetable Physiology and Pathology the results were given of extensive investigations, showing the cause of the disease, and the nature, habits, and relationships of the fungus producing it.

The efforts of the writer have been directed mainly toward the solution of some problems necessarily left unfinished by Dr. Smith, and especially toward finding a practicable remedy for the disease. This work has resulted in the discovery of a race of cowpea resistant to the attacks of the wilt fungus, and the experiments carried on by the Department indicate that it will be possible by careful selection to obtain other races adapted to different uses. The work has not yet been completed, but it is believed that the results already obtained justify publication, since the suggestions offered will afford relief to the farmers who have been troubled with the cowpea wilt, and because they may suggest methods that will also be useful in combating other diseases than the one treated here.

DESCRIPTION OF THE DISEASE.

The disease first appears when the plants are about six weeks old. Up to this time they will grow very well and appear perfectly healthy. Scattered plants then begin to drop their leaves, the lower ones falling first. Growth is checked, and the stem shows a faint reddish-brown tinge. After the leaves have fallen the stem becomes dead and covered with a light-pink coating of the spores of the wilt fungus (Pl. I). The spread of the disease is more gradual and less conspicuous in the early part of the season, but after the peas begin to set fruit they succumb very rapidly, and a field that in July may promise a fine crop may be entirely dead before September without having matured a pod. The disease usually appears in spots, like the cotton wilt, and these diseased areas spread until they may cover a whole field.

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[1] Smith, Erwin F., Wilt Disease of Cotton, Watermelon, and Cowpea, 1899.

In moderate cases, or where the varieties planted are less subject to the disease, only the weaker plants are killed, while the rest are dwarfed and their yield reduced. A careful examination of the roots will show that many of the small lateral roots are dead and small tufts of roots mark the points of infection (fig. 1). This tufting of the rootlets is similar to that produced on cotton by the cotton-wilt fungus.

In all cases the vascular tissue of the stem is brown, and the disease may be clearly distinguished by cutting across the stem and observing whether the color of the wood is normal. This discoloration is characteristic of this class of diseases. The term "wilt" is somewhat misleading, as the leaves usually drop off before there is any conspicuous wilting. The name was applied because of its relationship to the wilt of cotton and watermelons, where this symptom is very prominent, and it has seemed desirable to retain it for the cowpea disease.

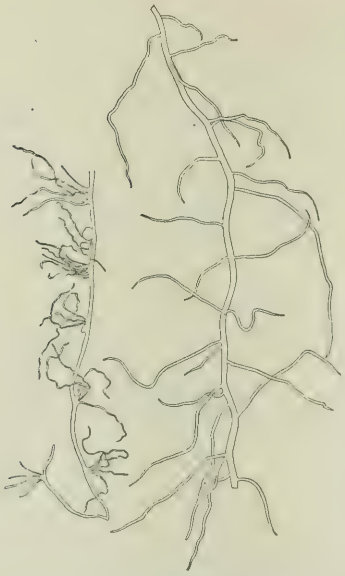

FIG. 1.—Roots of diseased cowpea, showing tufts produced by the wilt fungus, compared with healthy root.

CAUSE OF THE DISEASE.

The disease is caused by a fungus, *Neocosmospora vasinfecta*, var. *tracheiphila*, Erw. Sm.[1] It enters the plant from the soil through the smaller roots and grows through the water ducts of the stem until it may be found, in advanced cases, even in the smaller branches and the petioles of the leaves. The brown color of the wood is due to the action of the fungus on the walls of the vessel it occupies. The mycelium is nearly white, but it causes the walls of the vessels to become deeply stained. The fungus is not found outside of the water vessels while the plant is living. It is present within them in considerable quantities. Some of the vessels are completely filled with the interwoven hyphæ of the fungus, and the supply of water and plant food carried from the roots to the leaves is greatly diminished. The appearance of the plant affected by this disease indicates that it is suffering from a lack of water. Rains at this stage do not help it, however, and usually only a few days elapse after the disease appears before the plant is dead.

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[1] Described in Bul. 17, Div. Veg. Phys. and Path. Smith, Erwin F., Wilt Disease of Cotton, Watermelon, and Cowpea, 1899.

DESCRIPTION OF THE FUNGUS.

The following is a detailed description of the fungus:

The mycelium is 2–4 μ in diameter, septate, and branching freely. Its color inside the plant is hyaline or nearly so, but in pure cultures on certain media it becomes bright red or purple.[1] It produces spores (micro-conidia) inside the vessels of the living stem by abstriction from branches of the mycelium. They are hyaline, oval to narrowly elliptical, 4–25 μ by 2–6 μ, nonseptate, or sometimes uniseptate after abscission. The presence of these small conidia inside the water vessels affords a reliable means of distinguishing between this fungus and other species which may be found in the stems of diseased plants.

Other spores (macro-conidia), the *Fusarium* stage of the fungus, are borne in great profusion on the outer surface of the dead stems, or on dead, sunken spots on badly diseased stems, on small, oval conidia beds, consisting of short, irregular conidiaphores that are outgrowths of the internal fungus, as shown by the fact that the conidia beds are borne in parallel rows, which correspond to the vascular bundles inside the stem. The spores are lunulate, 3–5 septate, 30–50 μ by 4–6 μ, hyaline when examined separately, but in mass varying from nearly white to pink or deep salmon color.

The ascomycetous stage of the fungus is found on the roots of the dead plants, or occasionally on the parts above ground. The perithecia are small, bright-red bodies, borne singly or several together on the outer surface of the roots, ovate, variable in size, 250–350 μ by 200–300 μ; asci numerous, 8-spored, cylindric, stipitate; ascospores in one row, globose to short elliptical, rather thick-walled, colorless till ripe, then light brown, variable in size, 10–12 μ in diameter.

The cowpea fungus produces its perithecia very freely on dead plants, and the writer has also found them on the root tubercles of healthy plants of the Iron cowpea growing on infected land. The watermelon fungus produces perithecia less freely and apparently only under certain conditions or when at a certain stage of decay, while the cotton fungus forms them still more sparingly. Cultures made from ascospores of the cowpea fungus will reproduce ascospores in a week's time when grown on the proper media.

MANNER OF INFECTION AND SPREAD.

The fungus enters the plant through the small roots, producing on them little tufts which seem to be characteristic of this class of diseases. The manner in which the cowpea fungus spreads has not been fully investigated, but as far as now known it is like the cotton and watermelon wilts, which have been studied more carefully. The diseased areas in the fields increase in size quite rapidly by direct growth from the edges, which is probably due to the spread of the mycelium through the soil, though no experiments have been made to demonstrate this. The cotton fungus is carried by the plow and cultivator, as evidenced by its spread down the length of a field from a diseased area at one end, in cases observed by the writer; and by cattle, in cases where they passed through an infected field on their way to pasture. The watermelon fungus has been observed to spread from high to lower lands through the drainage water. The cowpea fungus produces spores in the greatest abundance, and there is every reason to believe that it spreads in all these ways.

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[1] Smith, Erwin F., l. c., p. 14.

It is difficult to account, by any of the causes just mentioned, for isolated outbreaks of the disease, which occur frequently where it had not been observed before. The fungus is undoubtedly widely distributed in places where it ordinarily causes little or no damage until some favorable conditions lead to an unusual development of it. The fact that the disease may occur in small quantities in a field without being noticed makes preventive measures, designed to limit the spread by destroying diseased plants, very nearly impracticable.

RELATION TO OTHER WILT DISEASES.

As already stated, the wilt of cowpea is closely allied to similar diseases widely prevalent on cotton, okra, watermelon, and other plants. The fungi causing these other diseases are considered to be varieties of the same species. As far as the appearance of the parasite is concerned there is no difference. When grown in pure culture, they can not be distinguished from each other. The manner of infection seems to be the same in all, and the effects produced are quite similar in all cases. The different diseases occur in nearly the same territory. It is well demonstrated, however, that they are not intercommunicable, i. e., the cowpea disease attacks nothing but cowpeas, the watermelon wilt nothing but watermelons, the cotton wilt only okra and cotton. The cross inoculations from pure cultures of the different fungi, reported by Dr. Smith[1] were all unsuccessful. Some experiments made by the writer of grafting pieces of diseased cowpea stems into cotton plants and vice versa were also unsuccessful. The writer has seen cowpeas perfectly free from disease in a very large number of cotton fields where the cotton wilt was present, and in several instances cowpeas have been observed to do well when grown in fields where watermelons were dying from wilt.

In Monetta, S. C., cowpeas thrive where watermelons die from wilt, and cotton does well where cowpeas are all killed. In Dillon both the cotton and cowpea are affected, while watermelons are healthy on the same land. It frequently happens that more than one of these diseases occur in the same field, but it has never been proved that one disease induces another. One instance, at least, has come to the attention of the writer where, at Salters, S. C., the three wilt diseases of cotton, watermelon, and cowpea all occurred in the same field. In the majority of cases, however, the occurrence of the disease on the different plants is sufficiently distinct to leave no doubt that they are noncommunicable.

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[1] Smith, Erwin F., l. c., p. 35.

DISTRIBUTION.

The disease is known to occur in North Carolina, South Carolina, and Alabama, and there is every probability that it will also be found in other States where cowpeas are grown. In South Carolina, where most of the investigations of this Department have been carried on, it has been found widespread in the counties of Aiken, Darlington, Saluda, Marion, Williamsburg, and Charleston. In all these cases it has been found to be more prevalent on sandy soils and in the higher, better drained portions of the fields, rather than in the lower and stiffer soils. In this respect it is like the cotton wilt and the watermelon wilt, which are both more injurious on sandy soils than on clay. It may occur on clay soils also, but it is believed the regions in greatest danger from the disease are the coast region, the pine belt, and sand hills, from North Carolina to Louisiana. It is to be looked for throughout this area. The writer has not had the opportunity of examining all this territory, but he has found the disease wherever he has searched for it and believes that futher observations will extend the area known to be infected with it.

EXTENT OF LOSS.

The disease has not yet become sufficiently widespread to cause serious loss except in a few localities, though the aggregate injury from it throughout the country must be very considerable. It is already a serious annoyance in many places and there is great danger of its future spread. This danger is emphasized by the recent rapid spread of the cotton wilt, a closely related disease, which is yearly becoming more prevalent and now causes immense damage in North Carolina, South Carolina, Georgia, Alabama, Mississippi, and Louisiana. If conditions favor its development and the proper means are not taken to check it, the cowpea wilt may become equally widespread and proportionately injurious.

The growing tendency toward diversification and rotation of crops in the South is leading to a much wider use of the cowpea than formerly and makes an understanding of its diseases of great importance.

The cowpea is the principal leguminous crop of the South. It is grown for hay, for forage, and for the crop of seed, but more than for any other reason because of its value as a fertilizer and soil renovator. In this use it fills one of the greatest needs of the South, where the hot summer sun hastens the destruction of the organic matter in the soil and the heavy rains leach out the soluble plant food from lands left unprotected through the winter. The fertility of the land can best be maintained by growing cowpeas or related plants and plowing them under to increase the amount of humus in the soil, or, better still, by feeding them to stock and returning the manure to the soil. The cowpea, in common with other plants of the bean family, is able to draw a part of its nitrogen from the air, so that the soil is left not only richer in vegetable matter than before, but richer in the most expensive fertilizing element, nitrogen, and the farmer need apply only the potash and phosphoric acid. A crop of cowpeas also improves the mechanical condition of the soil by the opening and loosening effect of its deep-feeding roots.

The cowpea succeeds well under widely diverse conditions of soil and climate, from the rich alluvial lowlands to the most barren and worn-out hillsides, and from the extreme South to the Central and Northern States. The methods of cultivation vary, but it is essentially a supplementary or intermediate crop. It is very often planted between the corn rows at the last cultivation, or it is sown broadcast or in drills, after grain or some early maturing crop has been removed. It is an excellent crop for planting in orchards and is much used for this purpose in the peach-growing districts. It is used in the trucking sections for planting between the rows of asparagus and to occupy the ground after an early spring crop is taken off.

Where the wilt disease is present in the soil, the injury to a second crop of cowpeas is likely to be much greater. It should be possible to grow cowpeas nearly every year on the same land, alone or in connection with other crops, but where the wilt fungus is present the peas die, and the farmers, with a partial understanding of the cause, say the land is "pea sick." The real reason for the failure of the peas is not the deficiency of any fertilizing elements, but because successive crops of cowpeas have so increased the amount of the wilt fungus in the soil that the ordinary varieties can not live. This "pea sickness" is believed to be due, in South Carolina at least, to the wilt disease, though sometimes peas are injured by the root nematode, or by a borer in the stem. The writer has known several instances where the wilt caused practically a complete destruction of the crop, but in the majority of instances only part of the plants were killed or only small areas in the field were badly attacked. Where peas are planted again on such land the injury is much greater. How long the land remains infected is not known in the case of the cowpea wilt, but the cotton-wilt fungus has been found in the soil after seven years in other crops, and probably is able to live for a much longer time. In the case of the cowpea, the amount of the wilt is greatly diminished when other crops intervene, according to the experience of Mr. T. S. Williams, who believes that rotation of crops will prevent serious loss from the wilt.

In many cases, however, it is desirable to grow cowpeas on the same land for several years, especially in orchards and on lands which it is desired to bring to a higher state of fertility. The occurrence of the wilt on such land prevents this from being done successfully. Even in the ordinary farm rotation cowpeas are often grown more than one year on the same land. For instance, the rotation most often recommended for the South by the best authorities is corn, with cowpeas between the rows; winter oats or wheat, followed by cowpeas; cotton.[1] From the nature of the disease, the writer doubts whether such a rotation as this would prevent injury from the cowpea wilt, if the ordinary varieties were grown, and believes that under present farm conditions the disease may become generally prevalent.

PREVENTIVE MEASURES.

ROTATION OF CROPS.

Where rotation is practiced there is less trouble with the disease. One or two years of other crops will reduce the amount of the disease so that it will not cause serious loss, though this relief is only temporary, as it is very doubtful whether the soil can be freed of the fungus in this way. It is probable that where a suitable rotation of crops is practiced this disease will not be very troublesome, but it has already been pointed out that there are many circumstances where it is desirable to grow cowpeas as a secondary or intermediate crop more or less continuously on the same land, and there are also many lands so badly infected with the fungus that ordinary rotation of crops will not be sufficient, and some other means of control must be adopted or the farmer will have to give up the growing of cowpeas.

SUBSTITUTION OF OTHER CROPS.

The alternative is left of growing some other leguminous crop, as in the experiments and observations of the Department no crop except the cowpea has been affected by this wilt disease. In many cases this can be done to good advantage, and unquestionably Southern agriculture would be benefited if a greater variety of legumes were used, but it must be admitted that no other crop adapted to Southern conditions can fully take the place of the cowpea, since no other can be put to such a variety of uses.

Among the forage plants tested by the Department the one most to be recommended as a substitute for the cowpea is the velvet bean. This is not subject to the wilt, but is somewhat liable to the attacks of the root-knot worm or nematode. It produces a heavy growth of forage and makes excellent hay, or plowed under makes a valuable fertilizer. It covers the ground well, and is superior to the cowpea for shading out grass. Its defects are that it requires a long season and does not ripen seed except in the extreme South, and the seed is expensive to buy. Its trailing habit and long runners make it difficult to cut and make into hay and hard to plow under, while it is objectionable in orchards on account of its tendency to climb into the trees.

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[1] Tracy, S. M., Farmers' Bulletin, No. 81.

The soy bean and Florida beggar weed may be used for hay as a summer crop, or hairy vetch may be sown in the fall. All these crops have in common the disadvantage of being unfamiliar to the average farmer, and consequently will be slow to come into general use, while the cowpea is cultivated and its use understood everywhere.

In view of the fact that rotation of crops is not always a practicable remedy and that there is no complete substitute for the cowpea, the value of a cowpea resistant to the disease is easily understood.

The possibility of combating the wilt in this way was suggested by the success of similar methods in dealing with the cotton wilt (see Bulletin 27, Division Vegetable Physiology and Pathology),[1] and it was learned from Mr. T. S. Williams, of Monetta, S. C., that a variety known as the Iron cowpea, cultivated by him, was resistant to the disease. Mr. Williams wrote August 25, 1900:

> I think you are working along the right line in trying to get a variety of melon with strong resistance to wilt. * * * I have a pea called the Iron pea, which is practically impervious to the pea wilt, or, as we call it, "pea sickness." This pea will make a fine crop on lands where peas have been planted a number of years and where other kinds will all die.

The writer visited Mr. Williams later in the season and saw the fields in question. The Iron pea was making a vigorous, healthy growth where other varieties had died the year before. The roots of these peas were examined and in many cases showed the little tufts of roots that indicate the presence of the wilt fungus in the soil. Occasional plants were found to be diseased and to have the perithecia of the wilt fungus on their roots. In one field where the Iron pea was growing by the side of the common field cowpea the Iron pea was healthy, while the other died very badly from the wilt disease. No nematodes were found in any of these fields. A neighbor of Mr. Williams, who for two years had all his peas die, planted the Iron pea this year (1901) at Mr. Williams's suggestion and made an excellent crop.

EXPERIMENTS WITH COWPEAS AND OTHER CROPS.

Arrangements were made for a careful test of different varieties the following season. This test was made by the Department in cooperation with Mr. Williams at Monetta, S. C., on land thoroughly infected with the cowpea wilt. One and one-half acres were planted May 29, 1901, to a number of varieties of cowpea, soy bean, velvet bean, and some Japanese forage plants obtained through the section of Seed and Plant Introduction of this Department. The soil was sandy, in good condition, and well fertilized. A crop of winter oats had been removed and the land thoroughly prepared. All the varieties tested were planted by hand in the same way, in rows about 3½ feet apart and 18 inches apart in the hill, two to ten seeds in a hill, according to the nature of the variety. The field was well cultivated. The care taken in planting insured a good stand, and nearly all the plats grew well until July.

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[1] Orton, W. A., Wilt Disease of Cotton and Its Control, 1900.

Scattered individuals in the different cowpea plats began to show the wilt disease early in July and as the summer progressed more and more succumbed. The amount of injury was increased by the presence in the soil of the root-knot worm or nematode (*Heterodera radicicola*) and by a severe drought in July and the early part of August. These conditions combined to make the test a very severe one.

The presence of the nematode in the soil complicated the problem, and special observations were made to find whether it or the wilt was responsible for the greater injury. The writer believes that the destruction of the cowpea in this experiment was due principally to the wilt fungus, though the damage was undoubtedly much increased by the attacks of the root nematode. The year previous cowpeas on neighboring fields were killed by the wilt and no nematodes found, while in many instances observed by the writer in other localities, where only the nematodes have been present, the injury to cowpeas has been much less.

The velvet beans did very well, making a heavy growth and producing a large crop of seed, which, however, did not mature. They seemed to be completely resistant to the wilt disease.

The soy beans were a disappointment, as they made a very small growth, one foot or so high, and produced only a small crop of seed. They were all badly attacked by the nematode and suffered much from dry weather.

The Japanese cowpeas tested proved to be very early varieties, maturing in two months from planting, when the American sorts were just beginning to blossom. They were small, but quite prolific, and were not greatly injured by the wilt. This was doubtless because of their extreme earliness, as they matured before the disease developed. These varieties would be valuable for trial in the North and for late planting in the South, but for general use they appear to be inferior to the common kinds. At the last they were considerably injured by wilt and the nematode.

Of the American cowpeas, all made a good start and had an equal chance, but none made any crop except the Iron.

A brief account of the behavior of these forage plants as grown on land infected with wilt disease and nematode follows:

Velvet bean (*Mucuna utilis*).—Seed from Florida. S. P. I.[1] Nos. 4333 and 5066, 3 plats. Growth vigorous and heavy. No injury from wilt, but somewhat injured by the root knot. Produced a fair crop of seed which did not mature.

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[1] S. P. I. Nos. refer to the serial numbers of the section of Seed and Plant Introduction, which kindly supplied much of the seed used in this experiment.

Soy bean (*Glycine hispida*).—Eight varieties were tried on ten plats. All proved to be immune to the wilt disease, but none of them was adapted to the local conditions. The growth was very small, the plants averaging from 8 to 14 inches high, though most of the varieties bore a good crop of seed for such small plants. All suffered much from drought in midsummer and all were badly injured by the root nematode. On examination of the roots a moderate number of bacterial tubercles were found, indicating that this plant is adapted to tubercle-forming organisms already present in the soil. The soil of the experimental field was a rather light sand and doubtless better results would have been obtained had it been more fertile, as the soy bean requires a richer soil than the cowpea. They were at a considerable disadvantage in this test, on account of the late date of planting and the ensuing dry weather. The soy bean has done well in the South when properly handled, and it is not unlikely that it may rank with the velvet bean as a desirable substitute for the cowpea on wilt-infected land. The writer planted it on Edisto Island, S. C., in 1900, where it made a heavy growth, 3 to 4 feet high, and produced a large crop of seed. It was free from wilt disease there and showed great promise as a forage crop.

The varieties tested at Monetta were as follows:

Best Green, S. P. I. No. 5766.—A late variety. It made a weak growth and suffered much from dry weather and root nematode.

Early Black, from France, S. P. I. No. 5039.—A small and early variety that fruited well, but made a poor growth.

Yoshioka, from Japan, S. P. I. No. 6314.—Early, with dark green and nearly smooth leaves; bore well, but was very small.

Rokugatsu, from Japan, S. P. I. No. 6326.—Early and very small, though bearing well.

Gosha, from Japan, S. P. I. No. 6333.—Early and small; suffered from drought.

Black Round, from Japan, S. P. I. No. 6334.—Early and small, bearing well for its size.

Green Medium, from Japan, S. P. I. No. 6335.—A later variety that made a more vigorous growth and lived through the season, while most of the preceding varieties died in August. It was badly affected by the root nematode.

Bakaziro, from Japan, S. P. I. No. 6336.—Medium early and very prolific, but much injured by drought and nematode.

Lablab Bean (*Dolichos Lablab*), from Japan.—Two varieties tested, the white (S. P. I. No. 6319) and the purple (S. P. I. No. 6320). These beans made a good growth early in the season. Vines long and trailing or climbing high on any support near. They began to blossom in August, but did not mature much seed. Later in the season they were very badly injured by the nematodes.

White Natamane (*Canavalia ensiformis*), from Japan, S. P. I. No. 6323.—A large-leaved, tall climber, blooming early in August and ripening its very large pods about November 1. No traces of wilt. There were plenty of nematode swellings on the roots, but the plants did not appear to be greatly injured by them.

Pink Natamane (*Canavalia gladiata*), from Japan, S. P. I. No. 6324.—Similar to the preceding. Neither these two nor the Lablab beans appear to have any special value as forage plants.

Muroran beans (*Phaseolus mungo-radiatus*), from Japan.—Two kinds were tested, one red (S. P. I. No. 6318) and one green seeded (S. P. I. No. 6321). These beans were very early, maturing in less than two months from planting, and very prolific, but the plants were very small, 8 to 12 inches high, so that they can not be said to have any value as a forage crop for that locality. They evidently require a more fertile soil. No traces of wilt were found. They were badly affected by the root nematode.

Red Fodder peas (*Pisum sativum*), from Japan, S. P. I. No. 6332. These were planted May 29, at the same time as the other forage crops, and would undoubtedly have done better if they had been planted earlier. They made very little growth and suffered from the hot, dry weather. No evidence of infection by the wilt fungus was observed.

A small quantity of the common wild coffee, *Cassia obtusifolia*, was planted here, as the writer found a wilt disease affecting it on James Island in 1899. No such disease appeared here. This weed has frequently been observed in fields where the cowpea disease was present, but has always been free from wilt, so that it is quite probable that the disease of cassia is distinct from the cowpea wilt, though the fungus causing it is closely related to the cowpea fungus.

Astragalus sinensis, *Lespedeza bicolor*, and *Vicia faba* were also planted, but failed to grow; so no results can be reported.

Seventeen varieties of cowpea were planted to test their resistance to wilt.

"*Turco fascula*," S. P. I. No. 3610, from Smyrna.—An early cowpea, which made a vigorous growth in the early part of the season, but was all killed by wilt before the end.

Cowpea from Alashehr, Asia Minor, S. P. I. No. 3627.—An early variety of medium growth and quite prolific; quite subject to wilt.

Cowpea from Smyrna, S. P. I. No. 3670.—An early sort of larger growth than the preceding and notably more resistant to the wilt disease, though not free from it.

Black Jurokusasage, S. P. I. No. 6311, from Japan.—A very early cowpea, and the most promising of the Japanese importations tested; plants medium or small, very prolific; pods long, 10 to 12 inches, with from 15 to 18 black seeds; subject to wilt and injured by dry weather, but nevertheless maturing a fair crop.

Kurakake, S. P. I. No. 6327, from Japan.—Early and small, but fruiting fairly well; pea white, with a black eye; badly injured by wilt and nematodes.

Kintohi, S. P. I. No. 6328, from Japan.—Early; a small, prolific variety, with small red seeds; injured by wilt and dry weather.

Black cowpea, from North Carolina.—This plant began to show the wilt disease before the middle of July and was badly injured by it, making a very small crop of peas. It was also much affected by the nematode.

Lady, from South Carolina.—A small white pea for table use. It made a good growth and appeared healthy and vigorous August 1. After this date it began to die from wilt and the whole plat was practically destroyed, no seed being obtained from it. The nematode was also bad on this variety.

Mixed, from Georgia.—Healthy till August, when it died very badly. At harvest time the majority of the plants were defoliated. Every hill had some dead, while in fully half the hills all were dead. No crop was matured. The nematode was bad on this plat.

Red Ripper, from Georgia.—This plat was badly injured by nematode and somewhat also by the wilt disease. It dropped its leaves badly, but ripened a small crop of seed. It appears to be partially resistant to the wilt, and selections from the resistant plants will doubtless prove more successful.

Southern, from North Carolina.—Earlier than the preceding varieties. It bore quite well and proved to be partially resistant to the wilt, more so, perhaps, than any other sort except the Iron. It was badly defoliated late in the season. Nematode swellings were found in abundance on the roots.

Speckled, from South Carolina.—Late and badly diseased with the wilt; very little crop matured; nematodes on every plant.

Taylor, from Virginia.—A vigorous grower early in the season. Later on it suffered badly from drought and was badly injured by wilt and nematodes, so that very little seed was obtained from this plat.

Unknown, from Georgia.—A medium early variety on which the wilt disease appeared very early. A large part of the plants were killed and the crop ripened was very light; nematodes abundant.

Wonderful, from North Carolina.—A vigorous grower; late in bearing. The injury from wilt was very great. Though a part of the plants retained their leaves practically no seed was matured; nematodes abundant on the roots.

Iron, from South Carolina.—There were four plats of this variety in different parts of the field, with other varieties in between, so that there was abundant opportunity for comparisons. Iron was almost entirely free from wilt throughout the season. It made a vigorous growth, and bore a large crop, while the other varieties mentioned above growing beside it were nearly a total failure. (Pl. II and Pl. III, fig. 2.) Careful examination of a large number of plants, made by the writer and by Mr. H. J. Webber, failed to show any wilt fungus except on occasional scattered plants. It was also especially noteworthy that this cowpea was almost entirely free from the root nematode. This point is treated in detail in the second part of this bulletin. During the dry weather in July and August, when other varieties were dropping their leaves and blossoms, the Iron did very well. Its powers of drought resistance were nearly as conspicuous as its resistance to disease, and the combined qualities certainly mark it as one of the hardiest varieties known.

The Iron cowpea is a compact vigorous plant, of medium size (Pl. III, fig. 1), somewhat trailing in habit, but less so than the Unknown. The foliage is dark green, with a peculiar bluish luster that distinguishes this variety from others. It is of the Clay type. The seeds are small and hard. The color is buff and somewhat variable, seeds of different shades being found in the same pod.

The plant begins to bloom in about two months from planting and continues up to frost. The crop is therefore ripened through rather a long season, which is something of a disadvantage, though it is partially compensated by the fact that the pods do not shell out in the field as freely as other sorts, and picking can therefore be deferred till late. It holds its leaves under adverse conditions of drought and disease better than any other kind tested, and is especially noteworthy for the way it remains green up to frost, very much later than other varieties. When cut for hay it sprouts freely from the stubble, and makes more second growth than is usual (Pl. IV, fig. 1).

The Iron cowpea has proved to be the solution of the wilt problem wherever it has been cultivated on "pea sick" lands in South Carolina, though more extended trials, now in progress by the Department, will be necessary to determine its value for other localities. The origin of the variety is uncertain. It was found in cultivation in Barnwell County, S. C., by Mr. T. S. Williams four years ago, and was brought to the attention of the Department by him.

Though it succeeds well on infected lands and produces good crops where others fail, it does not produce as much forage or seed as some of the other varieties, such as Unknown, and it will be desirable to carry on some plant-breeding work to remedy these faults, which the Department hopes to do in the future. It may also be possible, by selecting resistant plants of other varieties, to obtain new strains equally as good as the Iron.

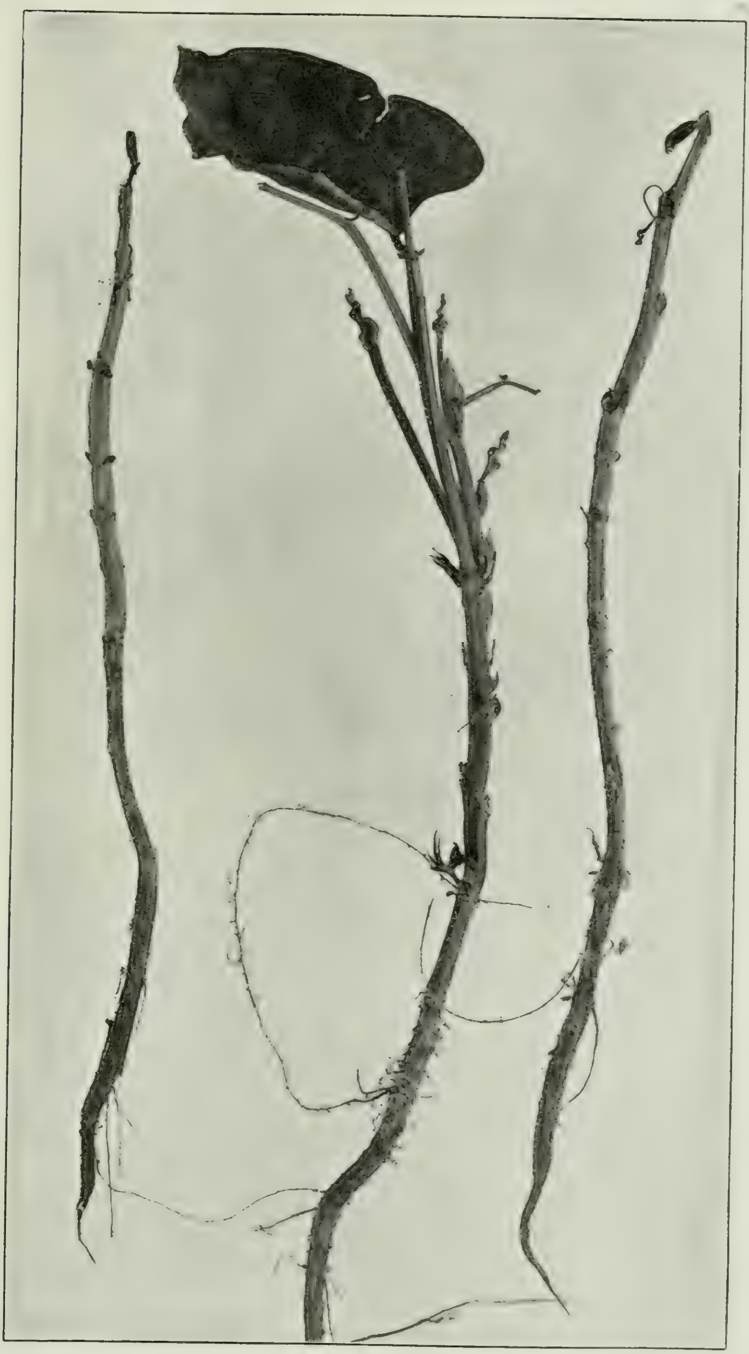
EXPLANATION OF PLATES.

Plate I. Specimens of Life-Preserver cowpea, showing different stages of the wilt disease; photographed July, 1901, Dillon, S. C.

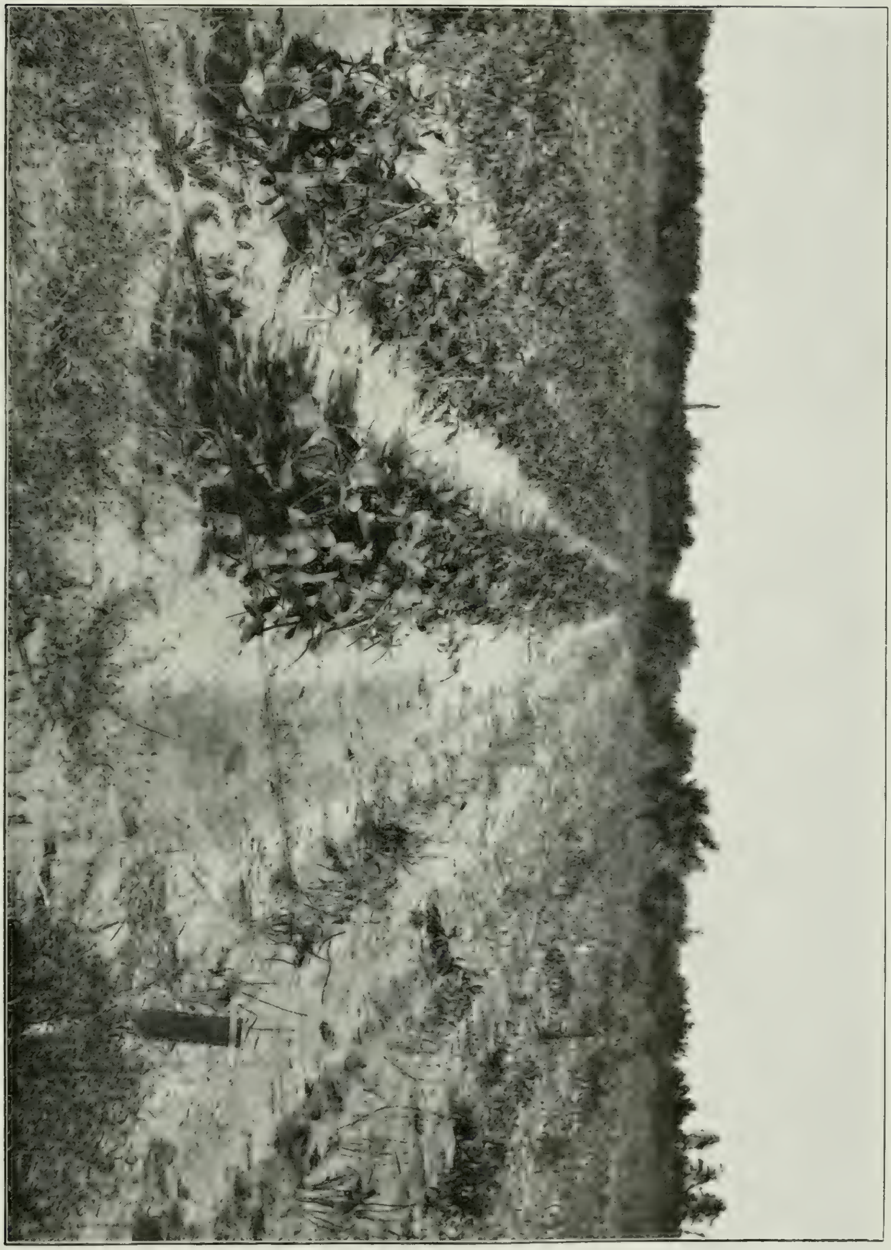
II. Experimental field at Monetta, S. C., showing comparative resistance of the Iron cowpea, on the left, and the Speckled cowpea on the right; photographed September, 1901, by Mr. H. J. Webber.

III. Fig. 1. Plants of Iron cowpea grown on infected land, showing condition October 24, 1901, Monetta, S. C. Fig. 2. Row of select Iron cowpea, planted between Black and Taylor cowpeas on experimental field at Monetta, S. C., showing comparative resistance to the wilt disease; photographed September, 1901, by Mr. H. J. Webber.

IV. Fig. 1. Iron cowpeas growing between rows of asparagus in wilt-infected field in Monetta, S. C., showing second growth after cutting for hay; photographed October 24, 1901. Fig. 2. Iron cowpeas in peach orchard, showing how the variety remains green until frost; photographed October 24, 1901.



THE WILT DISEASE OF COWPEA.



IRON COWPEA ON LEFT, SPECKLED COWPEA ON RIGHT, SHOWING COMPARATIVE RESISTANCE TO WILT AND ROOT KNOT.

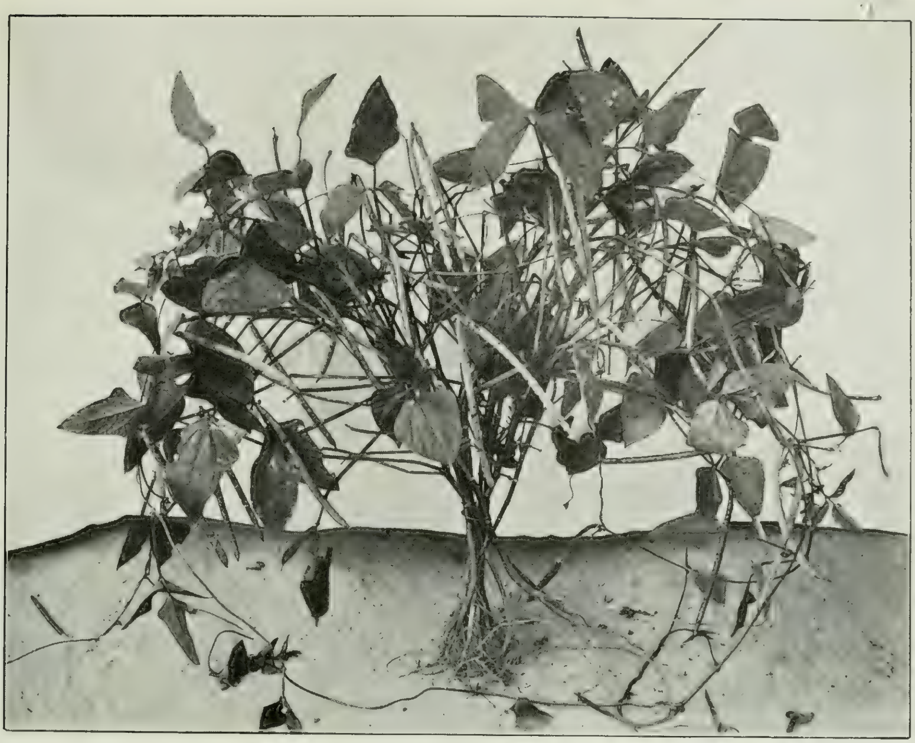
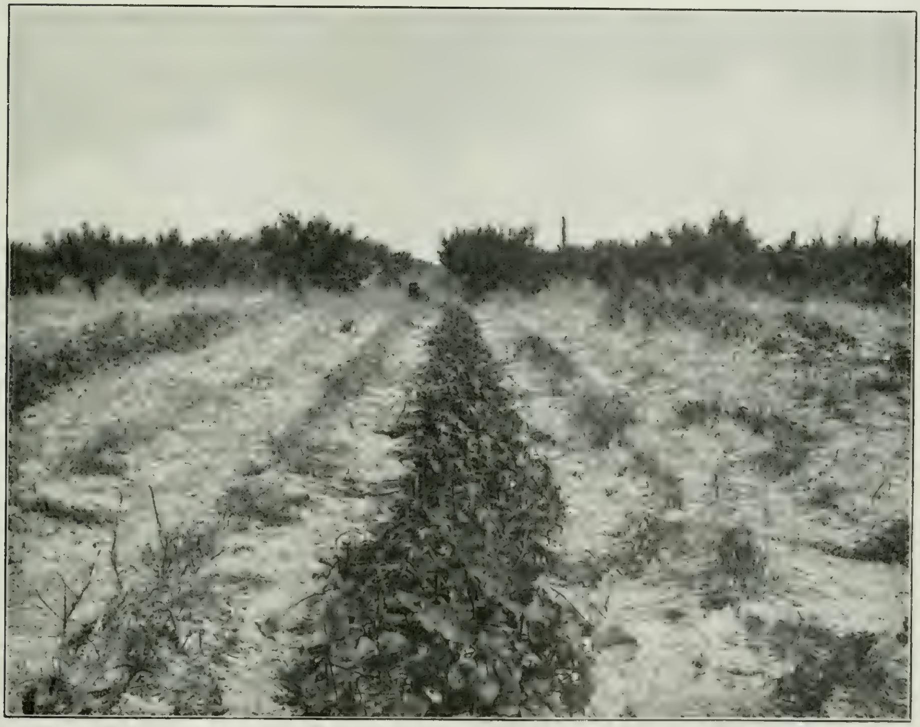


FIG. 1.—PLANTS OF IRON COWPEA, OCTOBER 26, 1901.



Taylor. Iron. Black.

FIG. 2.—IRON COWPEA VS. BLACK AND TAYLOR, SHOWING COMPARATIVE RESISTANCE TO THE WILT AND ROOT KNOT.

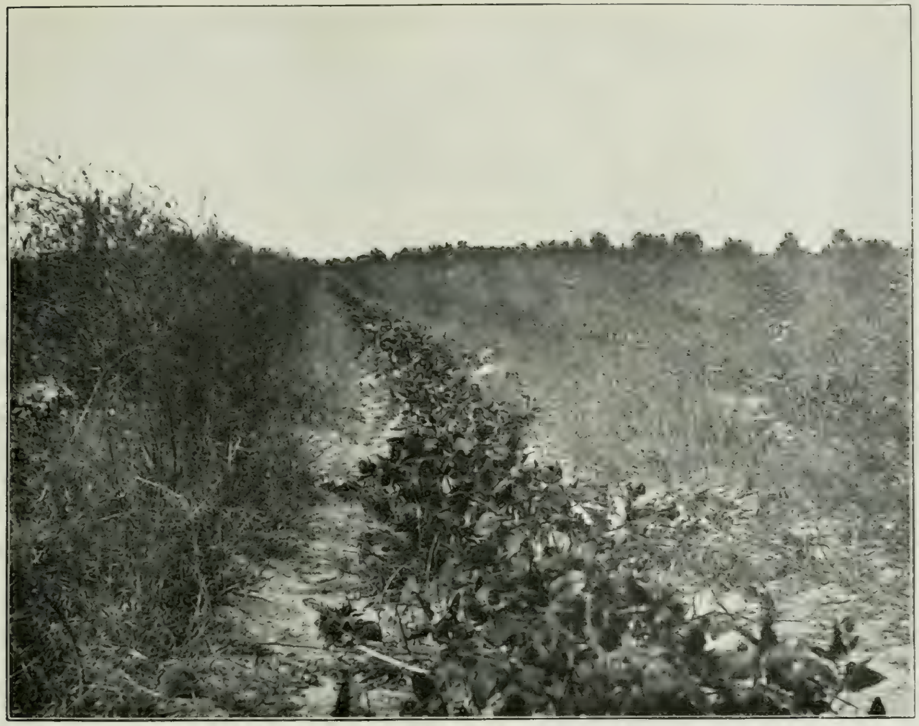


FIG. 1.—IRON COWPEA IN ASPARAGUS FIELD INFECTED WITH COWPEA WILT.

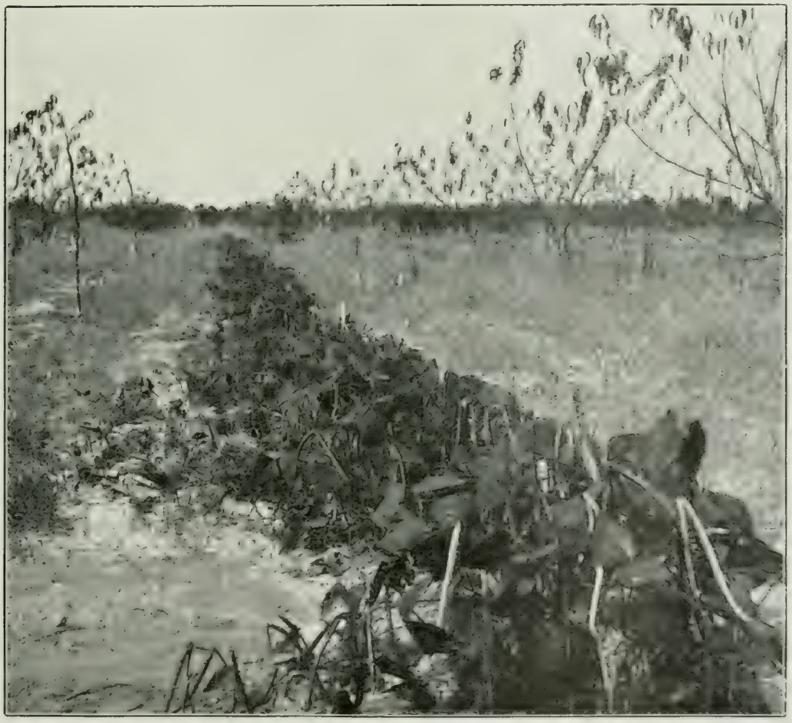


FIG. 2.—IRON COWPEA IN PEACH ORCHARD INFECTED WITH COWPEA WILT.

II. A COWPEA RESISTANT TO ROOT-KNOT (HETERODERA RADICICOLA).

By Herbert J. Webber, *Physiologist*, and W. A. Orton, *Assistant Pathologist.*

INTRODUCTION.

Root-knot, or root-gall, as it is ordinarily termed, is one of the most common and destructive plant diseases in the southern United States. The disease is caused by the attacks of a nematode, *Heterodera radicicola* (Greef.), Müll.,[1] which enters the roots and causes large galls. It is interesting to note that the nematode producing the root-knot of plants is closely related to the trichina of pork, which has become a household word and a universal terror.

DESCRIPTION OF THE DISEASE.

The characteristic external symptoms of the disease are the swollen, bead-like tumors produced on the roots. (Pl. VI.) Frequently the galls on badly diseased plants become so numerous that almost every root may be swollen to several times its normal size throughout almost its entire length. The organism attacks roots of practically any size, being common on both tap roots and smaller lateral roots. The surface of the gall is at first smooth, and later ordinarily becomes cracked, scurfy, and more or less decayed. There is a considerable variation in the forms of the galls on various plants, but there is a general similarity in all cases.

The nematodes, or nematode worms, as they are popularly called, though not true worms, when hatched from the eggs are embedded in the tissue of the old gall. From this they force their way through the tissue of the gall into fresh parts of the same root, where they take up their existence or force their way out of the old root into the soil and wander about until a satisfactory fresh root is found, into which they penetrate and form a new gall. They are so constituted that they can gradually make their way through the cells of a plant until they reach a satisfactory point for their development. Their irritation in the plant causes an abnormal enlargement of the tissue in their proximity, which leads to the formation of the large gall, which harbors and furnishes sustenance for the development of the organisms. The size of the gall is largely determined by the number of nematodes present. As new nematodes are hatched and take up their abode in fresh portions of the tissue the gall increases in size.

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[1] *Heterodera* is referred to in various publications under the generic names *Tylenchus* and *Anguillula*.

While the galls produced by nematodes are quite different from the bacterial root tubercles of leguminous plants and the root tumor of the peach and plum, they are nevertheless quite similar to certain root diseases, such as the swellings characteristic of "clubfoot" of cabbage (*Plasmodiophora brassicæ*), and the presence of the nematodes in the tissue forms the only absolutely sure determining character. Thin sections through the galls when examined under the microscope should show the eggs, larvæ, or cysts of the nematodes in some stage of development. The best descriptions of the development and metamorphosis of the root-knot nematode (*Heterodera radicicola*) known to the writers are those by Professor Atkinson,[1] then of the Alabama Experiment Station, and by Dr. G. E. Stone and Ralph E. Smith,[2] of the Hatch Experiment Station of Massachusetts. The reader is referred to these papers for further details of the development. According to Professor Atkinson, the length of time required for the completion of the entire life cycle in *Heterodera radicicola* is about one month. A knowledge of this fact is very important in applying the method of controlling the disease by planting catch-crops.

PLANTS AFFECTED.

In view of the possibility of breeding resistant strains of some plants, which will be discussed later, it becomes very interesting to note what plants are known to be affected by the nematode under consideration. Unfortunately, data upon this subject are rather incomplete. The following, which is one of the most trustworthy lists, is that given by Atkinson:[3]

Badly affected.

Solanum tuberosum (potato).
Lycopersicum esculentum (tomato).
Abutilon sp.
Vigna catjang (cowpea).
Lotus corniculatus (bird's foot clover).
Helianthus annuus (sunflower).
Citrullus vulgaris (watermelon).
Cucumis melo (nutmeg melon, citron).
Brassica oleracea (cabbage).

Slightly affected.

Amygdalus persica (peach).
Ficus carica (fig).
Vitis vinifera (grape, several varieties).
Solanum esculentum (eggplant).
Physalis sp.
Gossypium herbaceum (cotton).
Hibiscus esculentus (okra).
Sida spinosa.
Modiola multifida.

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[1] Atkinson, Geo. F. Nematode Root-Galls. A Preliminary Report on the Life History and the Metamorphosis of a Root-Gall Nematode, *Heterodera radicicola* (Greef.) Müll., and the Injuries produced by it upon the Roots of Various Plants. Rept. Agr. Exp. Station, Auburn, Ala. Bul. No. 9, New. Ser., Dec., 1889.

[2] Stone, G. E., and Smith, Ralph F Nematode Worms. Hatch Exp. Sta., Mass. Agr. Col., Bul. 55, Nov., 1898.

[3] Atkinson, l. c., p. 49.

Badly affected—Continued.

Brassica campestris rutabaga (rutabaga)
Pastinaca sativa (parsnip).
Tragopogon porrifolius (salsify).

Slightly affected—Continued.

Cassia obtusifolia (coffee weed).
Phaseolus.
Lespedeza striata (Japan clover).
Melilotus alba (sweet clover).
Ipomœa tamnifolia.
Ipomœa lacunosa.
Clematis.
Phytolacca decandra.
Beta vulgaris (beet).
Amarantus retroflexus (careless weed).
Chenopodium anthelminticum (wormseed).
Zea mays (corn).
Brassica rapa (turnip).
Marrubium vulgare (horehound).
Lactuca sativa (lettuce).

The above list was based on observations made simply at Auburn, Ala., and, according to Professor Atkinson, the presence of the nematode was determined microscopically in each case.

Dr. J. C. Neal[1] in his list of plants affected by this nematode in Florida enumerates 64 species, many of which are not given by Atkinson, but the above list will serve to show what widely different plants and families of plants are affected.

The same species of nematode affects many greenhouse plants in the North and frequently causes serious damage. The plants on which the most serious loss is produced under such conditions are the violet, rose, cyclamen, cucumber, and tomato.

EXTENT OF THE DISEASE.

The disease is evidently very common throughout the Gulf States and South Carolina, and may possibly extend farther northward. However, it will probably never become a serious malady north of this general region, except in greenhouses, as the nematode is killed by severe cold. Dr. Neal thought the northern extension to be not far from the January isotherm of 50°, as shown in No. 2 Isothermal Lines of the United States Signal Service, 1881. It certainly occurs much farther north than this, but data regarding its exact extent are very incomplete. The isotherm of 45° passes near Auburn, Ala., where Professor Atkinson's work was done; and Monetta, S. C., where the writers' observations were made, is probably north of this isotherm. In greenhouses in various parts of the North considerable damage is caused by the same nematode, and its control under such conditions has been made the subject of an exhaustive study by the Experiment Station of the

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[1] Neal, J. C.—The Root-knot Disease of the Peach, Orange, and Other Plants in Florida. U. S. Dept. of Agr., Div. of Entomology, Bul. No. 20, Washington, 1889.

Massachusetts Agricultural College.[1] The same species of nematode is known to occur in many parts of the world, and it would seem to be world-wide in its distribution. The writers have observed the disease in many different places in Florida, Georgia, Alabama, and South Carolina, and know it to be of common occurrence in those States. On the cowpea (Vigna catjang) in South Carolina it is very common and certainly causes considerable damage in lessening the quantity of fodder and peas produced.

Its greatest damage in the case of the cowpea, however, is probably due to its secondary action in spreading the nematode to other plants. It is not uncommon to hear peach growers of the South condemn the practice of growing the cowpea in peach and plum orchards because of the probability of its spreading root-knot. In Florida, where the beggar weed (Desmodium molle), which is said to be free from root-knot, is largely used in orchards as a cover crop and as green manure instead of the cowpea, the loss is said not to be so great. In more northern localities, however, where the beggar weed will not succeed, we as yet have no leguminous plant similar to the cowpea which could be recommended to take its place in orchards.

Nematodes frequently occur in connection with the wilt disease, and there is much greater injury done in such cases than would result from either one alone, but the two diseases are not necessarily connected nor dependent on each other. This is proved by the large number of cases observed by the writers where the wilt disease has been very destructive to cotton, cowpeas, watermelons, and other plants on land free from the nematode.

Of the two diseases of the cowpea, the root-knot is at present relatively more important on account of its wider distribution, and the fact that it attacks a large number of other crops, while the wilt disease so far as known is not communicable to other plants. If cowpeas or some other crop equally susceptible to the nematode be planted on infected land, they become badly diseased, and the number of nematodes in the soil is greatly increased, to the great detriment of succeeding crops.

Many farmers have expressed to the writers their belief that the cultivation of cowpeas increased the amount of wilt disease in succeeding cotton crops, but an examination of such fields have shown that the injurious effect of the cowpea crop was due to its action in fostering the root nematode. For this reason the resistance of the Iron cowpea described below, to the nematode, gives it special value for cotton planters.

In South Carolina the opinion is prevalent among planters that when cowpeas are grown continuously on the same soil for several years in succession that some fields, or patches in certain fields, become "pea-sick," as it is expressed; that is, so affected that they will not produce a crop of cowpeas, though some other crop may mature perfectly. Such conditions are interpreted ordinarily as being due to the exhaustion of some nutrient element in the soil necessary for the growth of cowpeas that may not be necessary for other crops. The writers have examined many cases of this kind in South Carolina and Alabama and have invariably found that the trouble was due either to attacks of wilt disease or root-knot or to the combined action of both of these maladies.

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[1] Stone, G. E., and Smith, Ralph E., l. c.

METHODS OF TREATING ROOT-KNOT.

The methods of treating root-knot which have thus far been employed are far from satisfactory. The following short review of these methods is introduced here mainly to call attention to the difficulty in preventing the disease by the application of treatments. A fuller discussion of the various methods can be found in the bulletins of Atkinson and Stone and Smith above referred to. Three methods in general have been suggested, namely: (1) Soil sterilization; (2) the action of toxic chemicals; and (3) the preparation of the plants to better withstand injury.

Soil sterilization.—Treatment by soil sterilization would include both the freeing of the land from the nematodes when once infested and the hygienic and other measures that may be employed to keep soils free from them. When fields have been badly infested the nematodes can probably best be killed out by growing on the land crops known to be unaffected until the nematodes have been killed by starvation. A proper rotation would also tend to keep the disease in check. The most practicable plan would be to keep the land in corn, oats, wheat, or grass for at least two years, using the greatest care to keep out all weeds, as so many plants are affected by root-knot that the disease is liable to be carried over and spread through their agency. The difficulty of sterilizing soil by starvation is readily seen when it is realized that during the entire time absolutely all weeds and plants subject to the disease must be prevented from growing. While this method of treatment is of great importance, the difficulty of its application renders it far from satisfactory.

In keeping the soil free from the nematodes it is important to remember that the larvæ and eggs are very minute and are easily carried from infested fields and spread to uninfested localities. They may be carried in the soil clinging to the feet of man or animals or to tools, or they may be blown about in the dust by the wind and washed here and there during heavy rain storms. Their distribution by the wind is hardly within control, but considerable can be done to prevent their spread by animals and by water in drainage. In preventing the spread of nematodes to perennials such as fruit trees the use of artificial, subterranean barriers which prevent the nematodes from passing freely through the soil to the tree has also been suggested, and while not altogether effective may be of some service. Such a barrier can be built around the tree, consisting of staves, scraps of galvanized sheet iron, or pieces of bark, placed close together. Burning brush or trash on the soil in sufficient quantity so that it is heated down for a foot or so has the effect of killing the nematodes, and places for planting susceptible trees can be sterilized in this way and reinfection partly prevented by artificial barriers. In greenhouses also heat is very effectively employed to sterilize the soil. In field operations frequent plowings in winter and in extreme dry spells have also been suggested as of benefit in destroying many of the larvæ in the soil by bringing them to the surface where they will be killed by freezing or by the action of the sun.

A unique method used to some extent by sugar-beet growers to reduce the numbers of the sugar-beet nematode (*Heterodera schachtii*) is that devised by Professor Kühn of trapping the larvæ by the use of catch plants. Strubell had shown that in this nematode about five or six weeks were required for the larvæ to reach maturity after entering the plant, and Kühn proposed to plant such crops as are selected most readily by the nematodes and at the end of a month, before eggs are produced, to pull them up and destroy them. At this time the oldest nematodes in the roots would not have produced eggs and the majority of them would have developed into motionless sacs, incapable of boring their way out, and would thus perish when the plants were removed from the soil. The crop of the catch plant can be used for forage or other purposes and thus partially pay for the expense of the treatment. Kühn's experiments have been characterized as a brilliant success, and some such method could doubtless be devised for the treatment of root-knot in this country, but so far as the writers are informed no careful experiments of this kind have so far been carried out with *Heterodera radicicola* where, according to Atkinson, the life cycle is much shorter, being about one month. Cobb,[1] in describing the occurrence of *Heterodera radicicola* in Australia recently, has suggested that mangels sown thickly and cowpeas would be promising to try as catch plants for this nematode.

Action of toxic chemicals.—The control of root-knot by the use of toxic chemicals is limited naturally to attempts to kill the larvæ in the soil, as it would seem to be impossible to kill them after they enter the plants without at the same time killing the plants. Neal and Stone and Smith in this country have made numerous experiments with various chemicals, but without obtaining satisfactory results in any case.

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[1] Cobb, N. A.—Root-Gall. The Agricultural Gazette of New South Wales, XII, p. 1046 (Sept. 1901).

Very many experiments have also been made with the nematode of the sugar beet (Rübenmüdigkeit), but the results thus far are mainly negative. No satisfactory chemical remedy has been discovered. Carbon bisulphide has proved to be effective in destroying the nematodes, but the expense of this treatment precludes its use on a large scale. The use of lime in large quantities has also been highly recommended, one or two tons per acre being used during the year in two or three applications.

The preparation of plants to withstand injury.—It has been learned by observation and experiment that certain chemicals tend to increase or diminish the disease owing to their effect on the plant. Highly nitrogenous manures which tend to cause a rapid growth of succulent, tender tissue, are said to increase the injury caused by root-knot, while heavy fertilization with sulphate or muriate of potash, which tend to produce a well-hardened, comparatively slow growth, is said to greatly lessen the injury.

THE USE OF RESISTANT VARIETIES AND STOCKS.

The first discussion which the writers have thus far found in literature of the possibility of controlling nematode diseases by the use of resistant varieties and stocks is that by Doctor Neal,[1] who says: "After all, I believe the use of trees that are not susceptible to the root-knot for stocks on which to graft or bud the susceptible varieties is the proper solution of the root-knot problem." Neal recommends the hardy bitter-sweet or sour orange as a species nearly proof against attacks of root-knot, and further states that *Citrus trifoliata* and the Satsuma or Onshiu orange seem to be resistant. In his list of plants affected by root-knot Neal includes the orange as one of the plants slightly affected. During a prolonged investigation of the diseases of the orange in Florida one of the writers dug up and carefully examined the roots of orange trees in all parts of the State, but was unable to find any trace of injury by nematodes. While negative evidence is always of doubtful value he is convinced that root-knot of the orange in Florida is at least of very rare occurrence. The resistance or nonresistance of any orange varieties or species under such conditions could hardly be conclusively determined.

According to Dr. Neal's statements, among grapes the *cordifolia* and *vulpina* races are largely free, while the *vinifera* and *æstivalis* groups are subject to the disease. He also states that the Wild Goose and Marianna plum stocks are largely immune. The evidence on which Neal's claims are based is not sufficiently given to enable one to judge of their value. If he is correct, their value has not been thoroughly appreciated. Some features of his investigations have been questioned, and this may have led to his valuable suggestion regarding the use of resistant strains being improperly appreciated.

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[1] Neal, l. c., p 22.

Zimmerman has also pointed out that the nematode attacking the coffee plant in Java only exceptionally affects Liberian coffee (*Coffea liberica*), but is very serious on Arabian coffee (*C. arabica*).[1] In an experiment in which healthy trees of both species were grown for over five months in the same pots with badly diseased plants, 95 per cent of the healthy trees of *C. arabica* became infected, while only 59 per cent of those of *C. liberica* showed the disease. The Arabian coffee sells in the market at a higher price than Liberian coffee, and Zimmerman recommends controlling the disease by grafting Arabian coffee upon the more resistant Liberian stock. This he says can be satisfactorily accomplished with the loss of only a few plants. The same method of controlling the coffee nematode has also been recommended more recently by Bonquet de la Grye.[2]

The only other suggestion regarding the use of immune strains in the treatment of nematode diseases that has come under the notice of the writers is that made last year by Wilfarth,[3] who conducted somewhat extensive experiments to demonstrate the possibility of breeding strains of the sugar beet resistant to nematodes. He states that in badly infected fields where the beets are abundantly infested there are always some individuals which show very few or almost no nematodes. In one of Wilfarth's experiments a large box was filled with soil which was thoroughly infested artificially with nematodes. In this box 205 beets were grown. Tests made from time to time showed the nematodes to be very abundant. The plants were examined at three different times to determine whether there was any difference in the time of infection. In general the plants were abundantly infected, about 18 per cent were badly infected and 28 per cent but slightly infected. Among those slightly infected were many with only a few nematodes. The percentages of badly and slightly infected plants at each harvesting period were about the same. From the results of the experiment it was inferred that the nematodes do not enter all beets indiscriminately, but find certain differences which render some beets more agreeable than others.

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[1] Zimmerman, A. Het Groepsgewijs afsterven der Koffie heesters in gesloten plantsoenen. Teysmannia, 1897, 23 pp.; also De Nematoden der Koffiewortels. I. Mededeelingen uit's Lands Plantentuin. 1898. No. 27, 64 pp. (German review in Centralbl. f. Bakt. Parasitenk. u. Infek. 2 Abt. 5, 415).

[2] Bonquet de la Grye. La Génération des Plantations de Caféières dans les Antilles. Bull. de Séances d. l. Soc. Nationale d'Agr. d. France. 1899. 683–687.

[3] Wilfarth, Prof. Dr. H. Ein neuer Gesichtspunkt zur Bekämpfung der Nematoden. Zeitschr. d. Ver. d. Deut. Zucker-Industrie. Lieferung, 529, pp. 195–204. Feb., 1900.

In another experiment 100 good, normal beets, wholly free from nematodes, were selected from a field free from nematodes and stored during the winter. In the spring each of these was cut into from ten to sixteen pieces of equal size, which were divided into two equal lots, the pieces from each beet being kept separate under the same number. These were then planted in a field badly infested with the nematodes, the two lots from the same beet being planted in different places. When the plants grown from these pieces were harvested and the abundance of nematodes observed they were found to follow a definite rule of abundance or susceptibility in all of the plants grown from cuttings of the same mother beet. For instance, the four pieces of beet No. 16, which stood in one row, all had very few nematodes, while the other beets on either side in the same row and in adjoining rows were uniformly badly infected. The four pieces of the same mother beet planted with the second lot under the same number were also but slightly infected. It can thus be safely concluded that this was a case of genuine resistance to the nematode. A number of the beets showed about the same degree of resistance, while others were resistant in a much less degree. The investigation indicates that certain beets possess a specific attraction or repulsion for the nematodes, and the latter can be explained, says Wilfarth, only by assuming that a certain protective apparatus or device exists in the beet which keeps the nematodes out. The injurious influence of the nematode shows in the reduced size, malformation, and diminished sugar content. If, therefore, we select from a badly infested field those beets for mothers which do not have these characters and are well-formed and rich in sugar content, we will secure the resistant beet that we seek. Wilfarth advocates selecting resistant mother beets on badly infested soils and growing seed from these on similarly badly infested soils, and again selecting those beets least affected among the progeny to use as mothers. By continuing such selections he believes that thoroughly resistant strains can be bred.

A RESISTANT COWPEA.

The above review of the methods of controlling nematode diseases is given to show the present understanding of the malady. No method of treatment has yet been devised that can in any way be considered satisfactory, and the breeding or discovery of resistant strains remains as yet largely as a suggestion. It is thus highly important that further information be obtained, particularly in regard to the resistance of strains of plants subject to the disease and the possibility of producing such strains by breeding. Under these conditions it is highly gratifying to be able to announce the discovery of a variety of cowpea which under existing conditions seems to be almost absolutely immune to the disease.

Its resistance was brought out by the experiments with cowpeas and other leguminous crops described in the first part of this bulletin. These varieties were planted on the farm of Mr. T. S. Williams, Monetta, S. C., on land infected with the wilt fungus, in order to determine their resistance to that malady. This land proved to be thoroughly infested with the root nematode, though that was not known when the field was selected. In making the examination of the cowpea roots for the wilt fungus it was observed that the great abundance of nematode galls on the roots of many varieties more or less complicated the matter, as it was difficult to determine what proportion of the injury observable was to be ascribed to the wilt and what to root knot. Some care was therefore exercised in each case to determine the abundance of the nematodes on each variety grown. The field on which the plants were grown was a level area, slightly lower than most of the surrounding land, but apparently thoroughly drained. The different varieties and species were planted in rows about 200 feet long and from one to four rows of a variety in a place. Of several of the varieties two plats were grown in the same field, but separated some little distance from each other. All the species and varieties of leguminous plants grown, except one, that were in proper condition when the observations were made were found to be affected with root-knot, and on the majority of varieties the disease was very bad. One variety of cowpea, the so-called "Iron," was so strikingly free from infection as to attract immediate attention. Two plats of this variety were grown, one of four rows and another of eleven rows, so that abundant opportunity was furnished for observation. Numerous plants were dug up here and there in each plat and only one individual plant was found which showed any trace of root-knot. The plat of four rows was in the center of the field, and on one side adjoined the plat of the "Unknown" cowpea and on the other side the "Speckled" cowpea. Both of these varieties were very badly affected with the root-knot, practically every plant being badly diseased, so that there can be no doubt that the Iron, growing only a few feet away, had every opportunity to become infected had it not been resistant to the nematode. It is interesting to note that the same variety is very resistant to wilt also. In a careful search through the same plat not a plant was found that exhibited the characteristic symptons of wilt, though this disease was also abundant in the two varieties growing on either side. The immunity of the Iron cowpea to wilt has been discussed in detail by one of the writers[1] in the preceding article of this bulletin.

The combined effect of root-knot and wilt on the cowpeas was very serious. The two plats of the Unknown and Speckled cowpeas on either side of the Iron were almost entirely destroyed. When examined a large number of the plants were dead, showing by the symptoms that they had succumbed to the combined effect of the two diseases. Many of the plants had dropped all their leaves but were still green, while some had a comparatively few leaves still attached and green. All of the plants were small and stunted, and in the case of the Unknown had been so badly injured that no fruit was produced. The other variety, the Speckled, had produced a small crop of peas but was comparatively a failure. The difference in appearance between these two plats and the plats of the Iron cowpea was most striking. The Iron had made a fine growth, was wholly free from disease, and was fruiting abundantly, being both in flower and fruit at the time examined. In the other plat of the Iron cowpea all of the plants examined were found to be equally resistant to those in the plat just described. The second plat was an exterior one at one side of the field, and thus had plats only on one side with which it could be compared. The plat next to it on this side was of Yainari (*Phaseolus mungo-radiatus*), an imported Japanese plant, which on careful examination was found to be very badly infested with nematodes, almost every plant showing their effects. It seemed to be free from attacks of the wilt fungus, however, as no plants showing this disease could be found in the plat.

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[1] Orton, W. A. The Wilt Disease of Cowpea and Its Control. U. S. Dept. Agr., Bureau Plant Industry. Bul. No. 17, Article 1, pp. —.

Only a short distance from the experimental plats a comparatively large field of the Iron cowpea was growing, which was examined and a number of plants pulled up without finding any trace of nematode infection. In another near-by field of an ordinary variety the root-knot was found in considerable abundance.

The Iron cowpea is quite distinct in character from any other variety known to the writers. One peculiarity is its habit of continuous blooming—it may have flowers and ripe fruit on the same plant. As a result of this it continues to ripen its seed over a considerable period and retains its foliage meanwhile. This is a decided disadvantage if the peas are grown for their fruit, but if the crop is grown for forage the attendant character of retaining their leaves green until frost allows the grower greater latitude in harvesting, and this may be a decided advantage. While some other varieties of cowpeas possess some qualities superior to the Iron, the latter is surely a good variety for general purposes and is especially valuable on account of its disease-resistant qualities. The variety and its history have been more thoroughly described by one of the writers[1] in the first article of this bulletin.

The varieties of cowpeas grown on which observations were made were the Wonderful, Southern, Black, Whip-poor-will, Lady, Red Ripper, Taylor, Unknown, Speckled, Kurakake (an imported Japanese variety), Section of Seed and Plant Introduction No. 6327, and Iron. In all these varieties except Iron it was difficult to find a single plant showing what could be considered normal roots and bacterial tubercles. (Pl. VI.) The roots of the Iron were uniformly fine and slender, showing no indication of root galls produced by nematodes, but abundant nitrogen tubercles here and there, many of them remaining attached to the plants when dug up, though many were doubtless pulled off in removing the plants from the soil. (Pl. V.)

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[1] Orton, W. A., l. c.

The Iron cowpea, because of its resistance to wilt and root-knot and hardiness in other respects, is certainly one of the most valuable varieties of cowpeas known, and, with our present knowledge, is to be highly recommended for cultivation on all soils that are known to be infested with one or the other of these diseases. On soils free from these diseases some other variety may give better results, though the Iron is a good hay variety. In peach and plum orchards and places where it is feared the cowpea would induce the spread of root-knot the Iron variety can be grown without danger. It can be recommended without reserve as the safest variety of cowpea known for growing in such cases.

It is hardly to be expected that the Iron will prove absolutely immune to attacks of nematodes under all conditions. It is well known that when the larvæ can find no suitable or agreeable food they will enter plants ordinarily free from their attacks. The cause for the resistance of the Iron cowpea is under investigation and will form the subject of a later report. It is impossible, with our present knowledge, to state whether or not the larvæ would be able to live and mature if they forced their way into the roots. It is certainly marvelous that closely related varieties of cowpeas should show such striking difference in their susceptibility to root-knot, when such a large number of species of plants belonging to widely different families are known to be attacked with apparently equal readiness by the nematode.

It is a matter of doubt whether the Iron will retain the same degree of immunity for an indefinite period. Changes in climate, soil, and manurial conditions may induce changes which would impair its degree of immunity. Professor Atkinson[1] mentions a case of variation in *Amarantus spinosus* which is interesting in this connection. This plant he finds to be free from nematode injury at Auburn, Ala., even in the immediate neighborhood of other badly diseased plants, while Dr. Neal reports the same species in Florida as the "most dreaded and destructive agent in the spread of root-knot." Sorauer[2] also refers to an interesting case of barley, which ordinarily is considered immune to attacks of the sugar-beet nematode (*Heterodera schachtii*). For three successive years a piece of badly infested land was sown with barley, and for the first two years no noticeable injury was produced. The third year, however, the crop was destroyed a short time before harvest by attacks of nematodes.

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[1] Atkinson, l. c., p. 46.

[2] Sorauer. Pflanzenkrankheiten.

Should the Iron cowpea lose its power of resistance when cultivated under different conditions, or after an extended period of cultivation on infested soil, it could probably be brought back to its full degree of immunity by a few generations of seed selection from the most resistant plants. Such selection could be easily made by pulling up, at the time of harvest, a large number of the plants grown on infested soil and taking seed from those found to be the least affected by the disease.

A number of leguminous plants were grown in the same experimental field as the cowpeas, on nematode and wilt infested soil, and the following are observations in regard to the abundance of nematode galls found on the roots of these:

Glycine hispida (Soy bean).
  Best Green, S. P. I.[1] No. 5766, badly affected.
  Early Black, S. P. I. No. 5039, badly affected.
  Green Medium, S. P. I. No. 6335, badly affected.
  Bakaziro, S. P. I. No. 6336, badly affected.
Dolichos lablab.
  Purple Dolichos, S. P. I. No. 6320, badly affected.
  White Dolichos, S. P. I. No. 6319, badly affected.
Phaseolus mungo-radiatus.
  Muroran bean, S. P. I. No. 6318, badly affected.
  Yainari bean, S. P. I. No. 6321, badly affected.
Mucuna utilis (Velvet bean).
  Seed from two sources, S. P. I. Nos. 4333 and 5066, considerably affected
Canavalia ensiformis.
  White Natamane, S. P. I. No. 6323, badly affected.

For a more detailed statement in regard to the characters and success of the above plants the reader is referred to Part I of this bulletin.

THE BREEDING OF NEMATODE-RESISTANT PLANTS.

The cases of nematode-resistant plants and varieties known show clearly that certain plants possess qualities which render them unsuitable to the nematodes without at the same time materially impairing their value for cultivation. It would thus seem that nature has put into our hands the means of controlling this serious malady. In pulling up numerous plants of various cowpea varieties in making the examination above described a considerable variation in the degree of infection of different plants of the same variety was easily observable. Some plants were very badly diseased and others but slightly diseased.

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[1] S. P. I. numbers referred to are those given by the Section of Seed and Plant Introduction of this Department.

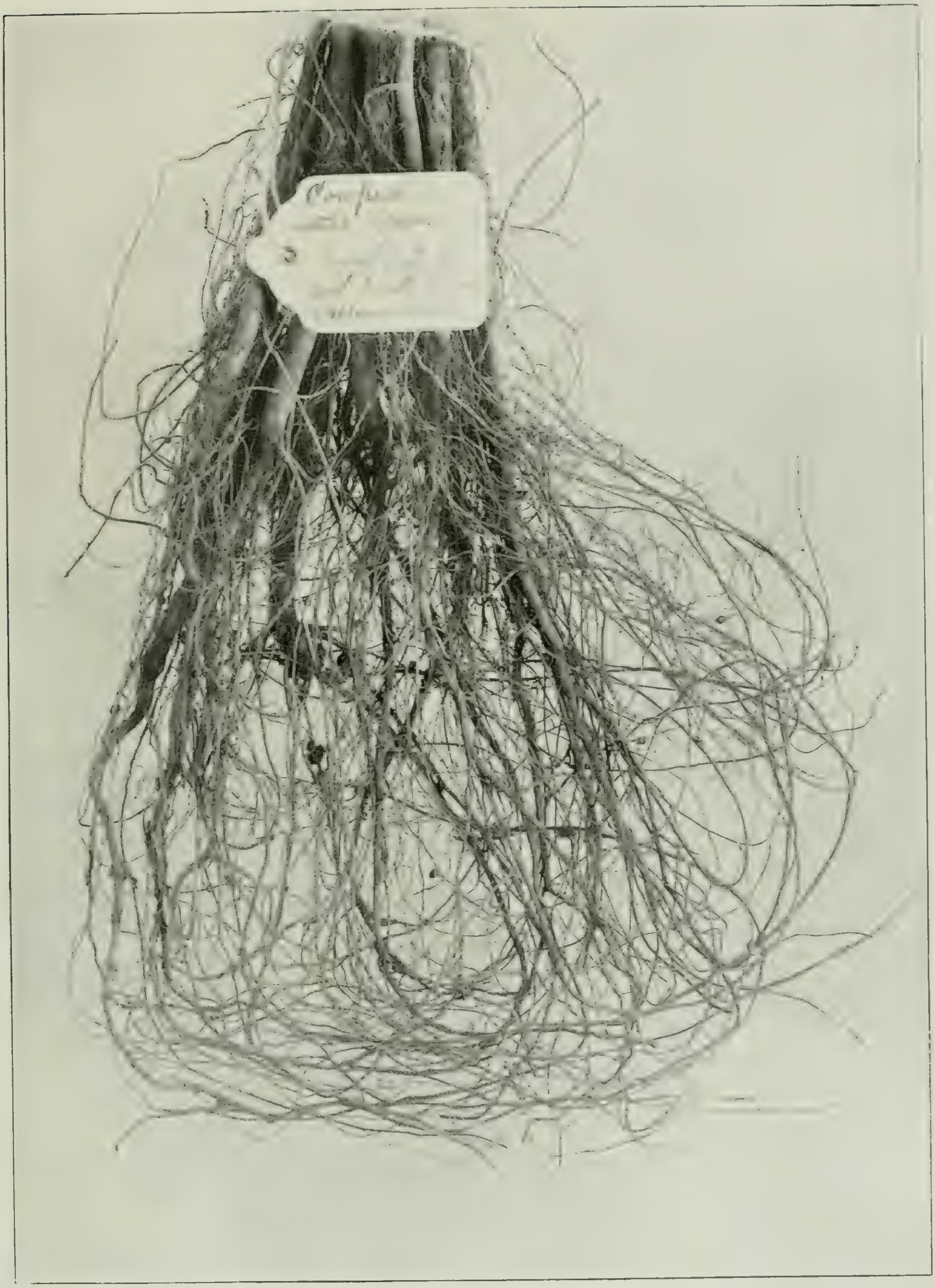
Whether this variation was due to accident or to inherent differences in the plants could not be determined, but it seems probable that a selection of seed from such slightly diseased plants continued through several generations, the plants being grown continuously on infested land, would ultimately lead to the production of an immune strain. The possibility of breeding nematode-resistant sugar beets has already been pointed out by Wilfarth, as indicated above. Mr. P. H. Dorsett informs the writer that in violet houses where the soil has become infested with root nematodes, he has observed a great difference in the susceptibility of different plants. If this is the case, we doubtless have here also the possibility of breeding resistant varieties.

The experience of the Department of Agriculture in breeding varieties of cotton resistant to wilt, and that of the French vineyardists in breeding grapes immune to *Phylloxera*, black rot, chlorosis, etc., shows how rapidly results of this nature can be obtained when intelligence is used in combining and selecting the best individuals. It may be possible to breed varieties of peaches, potatoes, tomatoes, cotton, etc., that will be resistant to root-knot, and we have here an interesting, extensive, and important field for experimentation.

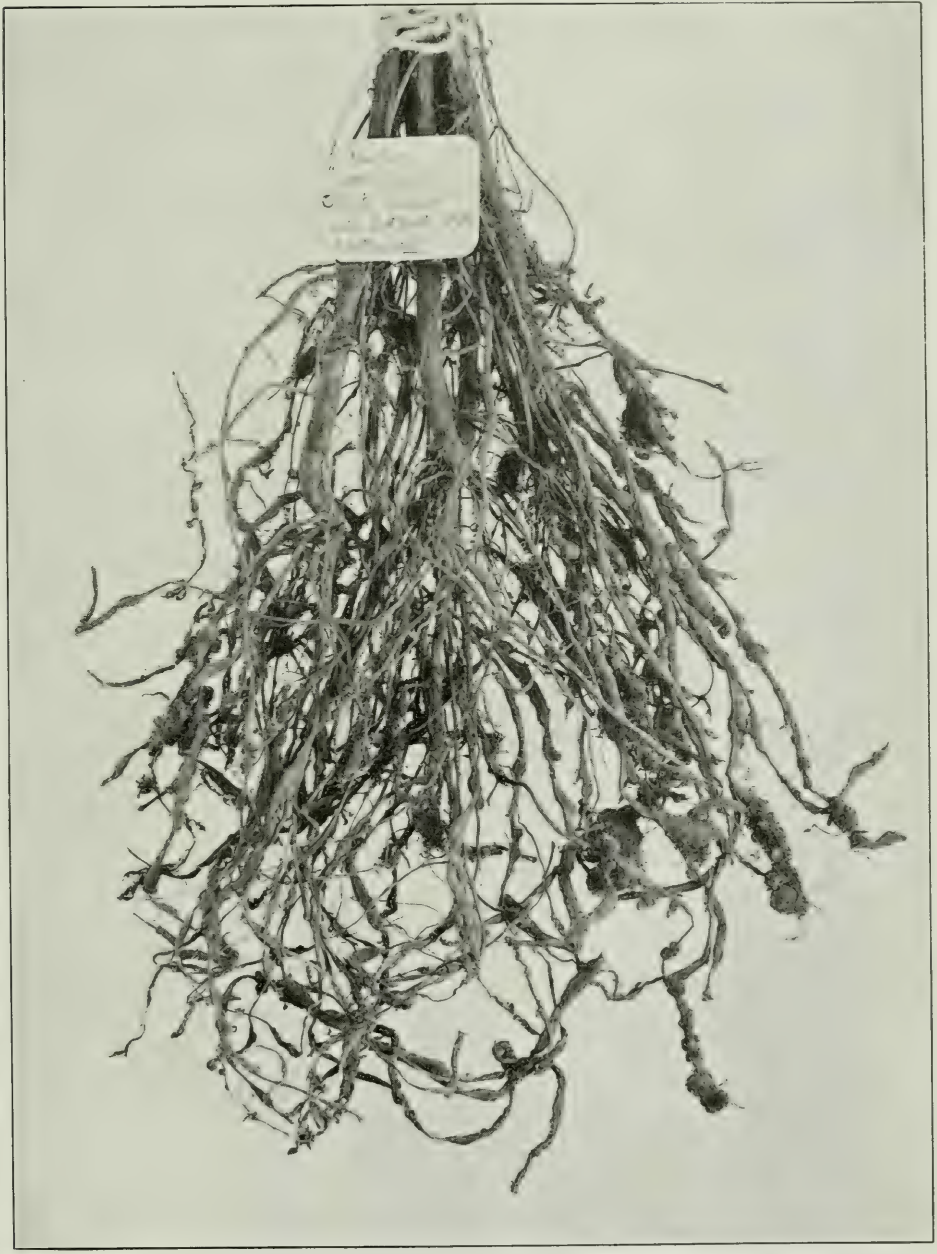
EXPLANATION OF PLATES.

Plate V. Roots of Iron Cowpea resistant to Root-knot. The ordinary nitrogen tubercles are shown here and there, but these are very different in form from nematode galls.

VI. Roots of Wonderful Cowpea, attacked by Root-knot. These were taken from the same field as the roots of the Iron Cowpea, illustrated in Plate V.



ROOTS OF IRON COWPEA. RESISTANT TO ROOT KNOT.



ROOTS OF WONDERFUL COWPEA FROM SAME FIELD AS THOSE IN PLATE V, ATTACKED BY ROOT KNOT.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN No. 18.

B. T. GALLOWAY, Chief of Bureau.

OBSERVATIONS

ON

THE MOSAIC DISEASE OF TOBACCO.

BY

ALBERT F. WOODS, PATHOLOGIST AND PHYSIOLOGIST,
VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ISSUED MAY 15, 1902.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 25, 1902.

Sir: I have the honor to transmit herewith a paper on Observations on the Mosaic Disease of Tobacco, and respectfully recommend that it be published as Bulletin No. 18 of the Bureau series. The paper was prepared by Mr. Albert F. Woods, Pathologist and Physiologist, Vegetable Pathological and Physiological Investigations.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The work described in this paper was started during the winter of 1898–99, continuing as other work permitted to the latter part of December, 1900, when it was brought together in its present form and presented December 27, 1900, at the Baltimore meeting of the Society for Plant Morphology and Physiology. Since that time the writer has been unable on account of other work to continue the investigation. It is believed, however, that the true nature of the mosaic disease of tobacco and of similar diseases of other plants has been found and that it will be possible in large measure to guard against them. Further investigation of some of the points left unsettled is at present in progress. The writer hopes that these may soon be settled with the help of Dr. R. E. B. McKenney, who has been assigned to the work.

ALBERT F. WOODS,
Pathologist and Physiologist.

OFFICE OF THE PATHOLOGIST AND PHYSIOLOGIST,
January 23, 1902.

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OBSERVATIONS ON THE MOSAIC DISEASE OF TOBACCO.

INTRODUCTION AND HISTORICAL SUMMARY.

This very singular disease of the tobacco leaf consists, in general appearance, in a more or less sharply defined differentiation into light and dark green areas, making the leaves have a more or less mosaic appearance. In the less pronounced cases the variation in the color is slight, but sufficiently marked to be at once apparent. In such cases there is very little distortion of the leaves. The light-green areas are, as a rule, between the larger vascular bundles. (Pls. I and VI.) The darker green portions form more or less of a border along the larger bundles. Occasionally, however, the dark and light green patches are not distributed with special reference to the vascular bundles, but occur indiscriminately. Where the contrast is more marked the light-colored, or sometimes even yellowish, areas grow slowly, while the dark-green areas grow more rapidly, and thus the leaf becomes badly distorted. (Pls. III and IV.) In some cases the whole plant becomes so deformed as to be almost unrecognizable. Even where the leaves are only slightly diseased and not deformed they are less elastic than the healthy leaves, and are not so suitable for wrappers for cigars, and have a poorer burn and aroma. The diseased plants do not grow as vigorously as healthy ones, but they usually produce flowers and fruit, and the seed, even from badly diseased plants, may produce healthy plants. There is no conclusive evidence that the plants from seeds of diseased plants are more subject to the disease than are those from the seeds of healthy plants.

The disease occurs more or less throughout the tobacco areas of this country and is widespread in Europe wherever tobacco is grown. As usual there are numerous theories in regard to its cause, many of which it will not be necessary to discuss here. Adolph Mayer[a] was the first to make a careful study of the trouble. He demonstrated that it could not be caused by an insufficient supply of mineral nutrients. He found as much nitrogen, potassium salts, phosphates, calcium, and magnesium present in the soils and plants where the disease occurred as in the soils where the disease did not occur. He also found that the trouble was distributed over a field apparently without regard to soil conditions.

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[a] Landw. Versuchsstation, 1886, Vol. XXXII.

Since tobacco requires much lime, liming of the soil was tried, but the disease was not prevented thereby. Mayer further kept hotbeds in some cases rather moist, in others dry, and then again richly or poorly manured with nitrogen; but in none of these cases could he determine that the conditions in question caused the disease. He also found that variations in the temperature of the hotbeds apparently had no effect; neither did crowding, which produced partial etiolation, appear to have any effect on the disease. Seeds from flowers in which self-fertilization was prevented he found to be just as susceptible to the disease as seeds produced without such precautions, but on soil on which the disease had once appeared it was again produced. According to his observations, also, the trouble was not often found on soil used for the first time for tobacco. He further proved that the juice of the diseased leaves injected into the growing parts of healthy tobacco produced the disease in the inoculated plants, while control plants injected with the juice of healthy plants did not develop the disease. He was also not able to produce it by injecting diseased juice into other solanaceous plants. Where the diseased juice was injected into tobacco the same trouble developed in from ten to eleven days. Heating to 60° C. did not destroy the infectious substance; at 65° C. to 75° C. it was attenuated, and at 80° C. it was killed.

After Mayer had shown the absence of animal and fungous parasites he supposed bacteria to be the cause of the disease, but all his efforts with bacteria cultivated from the surface of diseased leaves, and also with different mixtures of bacteria, failed to produce it. Nevertheless he thought that there must be certain pathogenic bacteria in those soils in which the disease appeared, and therefore proposed to change the soil in hotbeds and to devote the fields where tobacco had been cultivated and the disease had appeared to other crops. He also recommended the use of mineral rather than organic manures.

These general results were confirmed by several subsequent investigators. Not, however, until Beijerinck[a] took hold of the question was much of importance added to our knowledge of the malady. He proved the absence of bacteria in the development of the disease. He showed that the juice of diseased plants filtered through Chamberland filters, while remaining perfectly clear and free from bacteria, still retained the power of infection. A small drop of it injected hypodermically into a growing bud was sufficient to give the plant the disease. He found that only dividing (meristematic) cells can become diseased. Diseased tissue kept its infectious qualities even after drying, and retained its injurious properties in the soil during the winter. Weak solutions of formalin did not kill the virus, but heating to the boiling point did. Fresh, unfiltered juice was more effective than an equal amount of filtered juice. He found that soil around diseased plants may infect the roots of healthy plants, but he did not determine whether direct transference is possible through healthy root surfaces, or whether insects, by injuring the roots, favored infection. He defines the milder form of the disease as a suffering of the chlorophyll bodies. Later on a general disease of the entire plasmatic contents of the cells sets in.

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[a] Verhandelingen der Koninklijke Akademie van Wetenschappen te Amsterdam, 1898.

In field conditions as a final stage the swollen green areas became marked with small dead spots, but these did not appear in plants grown under glass. Under certain conditions he observed that plants apparently recovered from the disease; that is, the new growth appeared to recover. He found that the infective material, whatever it might be, could be transported through considerable distances in the plant, but could cause the disease only in dividing cells. He assumed the virus to be a noncorpuscular, fluid-like material, which had the power of growth when in contact, in a sort of symbiotic way, with growing cells—"a living fluid contagium."

Shortly after Beijerinck's paper, Sturgis published a critical review of all the work done on the disease up to that time, with numerous valuable observations made in Connecticut, where the trouble is known as "calico," or "mottled top." He presents the following summary of his observations and conclusions:[a]

> 1. The peculiar appearances known as "calico" and "mottled top" of tobacco are probably symptoms of one and the same disease. The former may occur very early in the life of the plant, even in the seed bed, and usually attacks first the older leaves. The latter occurs later, is less pronounced, and affects only the topmost leaves.
>
> 2. The disease occurs abundantly in some localities, notably on the close, clayey soils on the east side of the Connecticut River; sparingly in other localities, where the soil is open and porous.
>
> 3. The disease is not contagious. As to its infectiousness, no direct statement can as yet be made.
>
> 4. It is not caused by predaceous insects, nematodes, or parasitic fungi.
>
> 5. Bacteria have not been seen associated with the disease, but no critical method for their isolation or culture has been applied, and therefore the question of their influence can not at present be answered. The facts observed, however, are not favorable to the theory of bacterial infection.
>
> 6. The disease is not inherent in the seed. Seed from badly calicoed plants may produce perfectly sound plants, and vice versa.
>
> 7. It seems probable that the disease is purely a physiological one, caused primarily by sudden changes or atmospheric conditions which disturb the normal balance between evaporation of water from the leaves and its absorption by the roots, and secondarily by soil conditions which prevent the speedy restoration of that balance. This supposition is supported by numerous facts.

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[a] Conn. Expt. Sta. Report for 1898, pp. 252, 253.

Koning, as a result of his investigations of the trouble, very largely confirmed the work of Beijerinck and others.[a] My own study of the disease, briefly described in Centralblatt für Bacteriologie, Parasitenkunde, u. Infektionskrankheiten, Abt. 2, Band V, 1899, also agreed in the main with what I have already outlined as observed by other investigators. I pointed out in addition that the mosaic disease of tobacco was always accompanied by an excessive quantity or an excessive activity in the diseased cells of an enzym belonging to the oxidases, agreeing in this and some other important particulars with the changes known as variegation and albinism in various other plants, and often developing into this malady in tobacco. In all of these cases careful comparative investigation showed that the power of oxidation in the cells is inversely proportional to the amount of chlorophyll present, judging by color. Somewhat later I pointed out[b] an important structural difference between the cells of the green areas and those of the light. In the latter, in the less pronounced cases of the disease, there is a shortening and broadening of the palisade parenchyma cells, and in the more pronounced cases there is an entire suppression of these cells, so that on simply looking across the surface of the leaf depressions are seen where the light areas occur and apparent blister-like development in the green areas (Pl. I). As a rule the modified cells pass abruptly into the normal cells of the green areas. The palisade cells of healthy leaves and of the healthy areas of diseased leaves are from three to four times as long as broad. Some plants are dark green, and these have the longest and narrowest palisade cells, closely packed with dark-green chloroplasts, which seldom contain large starch grains. Other plants are much lighter in color. These have relatively broader palisade cells, approaching more in size and shape the spongy parenchyma cells of the same leaf. In both the light and the dark leaves the spongy parenchyma cells are about isodiametric, the diameter being about twice the length of the contiguous palisade cells in the mature leaf. In both the dark and the light leaves the number of chloroplasts is somewhat greater in the palisade cells than in the spongy cells, but their shape, size, and intensity of color are apparently the same in the same leaf. The wider palisade cells of the light type of leaves permit the light to pass through them more readily, the spaces between the chloroplasts being larger and the intercellular spaces fewer.

In comparing light and dark leaves there was also found a slight difference in the intensity of the color of the chloroplasts. Less green can be extracted from a given area of light leaf than from the same area of dark leaf, and this difference is also apparent in microscopic examination of the chloroplasts. The light-colored leaves show a greater tendency to store starch than do the darker ones, and they are slightly richer in oxidizing enzyms. In these particulars, therefore, they suggest a variation toward a condition found in moderately diseased cells. I have not observed, however, any greater tendency in these light-colored plants to develop the true mosaic appearance either naturally or under artificial manipulation. That the disease is not primarily of the chloroplasts, as Beijerinck thought, is evident from the fact that in the less pronounced cases the chloroplasts, though fewer in number, are not decreased in size or activity. However, the starch which they make is, as I pointed out in the paper cited, not readily converted into sugar, and hence is translocated with great difficulty. In some pronounced cases the chloroplasts are light-colored, or are wholly without color. This condition, however, appears to be a result rather than the primary cause of the diseased condition of the cells.

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[a] Zeitschrift für Pflanzenkrankheiten, Band IX, Heft 2.

[b] Science, n. s. 11, No. 262, pp. 17–19.

The conditions which cause the disease are certainly only effective when acting on meristematic or dividing cells. It can not be induced artificially, and never appears naturally, in cells which have stopped dividing. A diseased spot, therefore, never increases in size in a leaf except as the diseased cells themselves enlarge. The mosaic nature of the trouble and the fact that under some conditions the plants may grow out of the disease suggests that it must arise in such cases in the meristematic tissues behind the growing point, or, where the plant is not mosaic, but evenly diseased, the pathological condition must be present throughout the cells of the growing point.

TRANSLOCATION OF STARCH.

Examination[a] of the diseased spots early in the morning shows only a small decrease in the starch content of the cells from that present in them the previous afternoon, while the green, healthy tissues contain no starch, or only traces of it. It was thought that possibly the increase of oxidizing enzyms might either inhibit the production of diastase of the cells or inhibit the action of diastase upon starch. In order to settle this point strong solutions of the oxidizing enzyms of tobacco were prepared from diseased plants growing in the greenhouse in December, and after heating some of the solution to the boiling point, thus killing these enzyms, comparisons of the heated and unheated juice were made by adding 10 milligrams of taka diastase in solution to each of the tubes of juice to be tested. Equal quantities of freshly prepared potato-starch paste were then added to each tube and the tubes kept at 45° C. It was found that in a solution without oxidizing enzyms the starch was completely converted into sugar in thirty minutes, while the solutions in which these enzyms were active carried the change of the starch only to the erythro-dextrin stage in the same time. The action of the diastase of malt added in solution in the same quantity was somewhat less rapid than that of taka diastase, but the relative effects were the same, i. e., the presence of the oxidizing enzyms in solution had a marked inhibitory action on the activity of the diastase.

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[a] The most favorable method of examining the leaf for starch is to kill it in hot water, decolorize with alcohol, and immerse in iodine-potassium iodide solution. Very good results are obtained by immersing one minute in boiling water, transferring to cold water, then to the iodine solution, and examining by transmitted light.

In these tests the amount of diastase compared with oxidase was much greater than occurs in the diseased cells, so it is likely that the inhibitory action of the oxidase in the cells is much greater than that shown in the tests outside the cells. It would seem a warrantable conclusion, therefore, that in plants grown under glass in winter the tardiness in the translocation of starch in the diseased areas is to be explained by the abnormal activity of the oxidizing enzyms of these cells, and that the mode of this action is by retarding or weakening the activity of the diastase. This action of the oxidizing enzyms upon the diastase therefore retards the production of sugar and, consequently, of proteids and reserve nitrogen in general. It is probably on account of this that the cells of the diseased areas are relatively very poor in reserve nitrogen.[a] The slower growth of the diseased areas is most probably the result of this decrease in the availability of reserve organic materials—sugar and proteids. Whether this holds for the summer-growing periods is still to be determined. The inhibiting action is probably much less marked during warm weather.

ARTIFICIAL PRODUCTION OF THE DISEASE.

I have already pointed out that the mosaic disease may be easily produced by removing the top of a rapidly growing plant in any stage of growth. A few buds at the base of the stock must of course be left, and it is best also to leave a few leaves. The shoots that develop after cutting are, in practically every case, badly diseased. During the past year I have produced the disease in this way in plants only 4 inches high in the seed bed, and also by cutting back fruiting plants 3 to 4 feet high. Over 200 plants of various ages were cut back, and the new growth came diseased in every case. I have also experimented in the same way with tomatoes, potatoes, petunias, English violets, pokeweed (Phytolacca), and other plants, and find that the same disease can be produced in them by removing their tops and forcing sprouts to grow from the stems. Sometimes one cutting back is sufficient to produce a well-marked case of the disease, but usually in the tomato and potato two removals of the top are necessary. Plates II,

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[a] Loew. Physiological Studies of Connecticut Leaf Tobacco. Report 65, U. S. Dept. of Agr., pp. 11–25.

V, and VI show the disease produced in tomato and Phytolacca in this way. In these plants, as in tobacco, the diseased cells are greatly retarded in growth. They are rich in oxidizing enzyms, poor in proteids (soluble nitrogen), and have a tendency to store their starch rather than to convert it into sugar and translocate it. The most important thing that at once suggests itself in connection with the cutting back is the removal by this process of the large amount of reserve material that furnishes the food for roots and new growth.

When the top is cut off the small amount of the available reserve food left in the remaining parts would be expected to migrate in the direction of the demand of the roots. A new shoot which starts has to furnish not only its own organic food, but is drawn upon by the roots. It, of course, has an abundant supply of water and soil nutrients, but it is lacking in sufficient organic food—sugar and proteids—to meet the demands of the rapidly developing cells. The young dividing cells can not make direct use of the ordinary soil nitrates. Nitrate of potash, for example, may accumulate in a plant under various conditions, such as insufficient light, lack of the proper development of the chloroplasts, as in variegated plants, etc. Overfeeding with nitrates often causes a yellowing of the chloroplasts, probably by the accumulation of unused nitrates in the cells. A similar condition of food distribution may also develop in the formation of sprouts where they occur on a rapidly growing plant. In such cases they are as a rule badly diseased. When mosaic sprouts once develop on a plant all the new growth afterwards is likely to be mosaic, though of course the leaves already formed are not affected and the plant may not be commercially injured, as the sprouts and top will be cut away. Sometimes a perfectly healthy plant produces a few mosaic leaves at the top just as the flower stems begin to develop. This suggests the possibility that the developing flower stems get most of the organic food during the first stages at least of the development of these leaves. Removal of the flower buds, even if done at the first appearance of the disease, does not cure the trouble, though the leaves will make a much more vigorous growth than they otherwise would. In such cases, after the removal of the flowering buds, there is a tendency to produce flowering suckers. These always come diseased. It is very evident, in such cases as I have just described, that the trouble *can not be due to parasites and must be attributed to a disturbance of the normal physiological activity of the cells in question.* That this disturbance is primarily one of nutrition is indicated by facts already pointed out and others to be presented in the following pages.

Prof. U. Suzuki, Imperial University of Japan,[a] has made a very careful study of the so-called mulberry dwarf troubles in that country. As it is evident that the trouble is related to the one under discussion here,[a] I quote in the following paragraph from his report on the subject. It is the custom in Japan to cut back the mulberry trees each year to stimulate a new growth of branches and tender leaves for the silkworm. There are three principal methods of cutting: Low cutting close to the ground; medium cutting, leaving stumps about a foot high; and high cutting, leaving stems about 6 feet high. The cutting is done about the third year of the life of the plant, and usually in June, at the time of the fullest development of the leaves.

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[a] Bulletin of the College of Agriculture, Imperial University, Tokyo, IV., No. 3, July, 1900.

> By August or September the new shoots reach a height of 5 or 6 feet, and these are again cut down in May of the next year. This treatment secures a large crop and lessens the injury from insects and fungi. * * * The first sign of the disease usually appears on new shoots springing from stumps. When these have reached a height of 1 foot or so the upper leaves either begin to shrivel or manifest other signs of debility; and, as the shoots continue to lengthen, all the new leaves developed from them betray the same character. The diseased leaves may turn yellowish or remain a dirty green. * * * In acute cases the leaves may all shrivel up in one year, but usually only a few leaves near the top of the shoot betray their debility, whence the disease spreads with each successive cutting, until in the course of a few years the entire plant is attacked or even dies off. The branches of the attacked plants usually remain slender, and the twigs and leaves are very numerous. * * * Sometimes also the branches lose their strength and become procumbent. The unfailing signs are the imperfect development and shriveling of the leaves and the slenderness and dwarfed condition of the branches. Moreover, when a plant is once attacked recovery is possible only after two or three years of complete protection from cutting.

After an extended examination it was found that the trouble was largely confined to plants that had been subjected to low cutting, as described. It occasionally, however, developed on young plants which had never been cut, and sometimes on older plants which had never been subjected to cutting. These cases were very rare, but the cause of the disease in these was found to be due to a lack of sufficient reserve food to meet the demands of the growth. How this came about in the absence of cutting was not definitely determined, though it is clear, as the result of experiments which I will speak of later, that it might be caused by defoliation following insect or fungous attacks.

By an extensive series of analyses it was found that during the period of growth of the mulberry the reserve materials, principally the nonalbuminoid nitrogen (amido compounds soluble in water), in the bark of roots and stems are all transported to the growing parts and reach the minimum, and therefore if the plants are cut down in this period the new shoots are forced to depend on an exceedingly small quantity of reserve food; hence the leaves are imperfectly developed and the reserve materials are exhausted before the plants can absorb and assimilate adequate nourishment from the soil and the atmosphere. Professor Suzuki therefore concludes that the principal cause of the disease is to be sought in the practice of subjecting the mulberry to repeated low cutting, thus removing the reserve food required in growth. He also found that frequent picking of the leaves exhausted the reserve materials in the stems and caused new leaves to become diseased. He determined that some varieties of mulberry store large quantities of reserve materials and others very little. The former are quite resistant to injuries from cutting back and by the removal of leaves, while the latter are very easily injured in these ways. Winter cutting of dormant wood does not produce the disease, because sufficient reserve food is left.

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[a] Dr. Loew, in a letter dated December 12, writes as follows: "The observation that you made that oxidase can kill diastase has been also made by my assistant (Suzuki) in the case of mulberry leaves. Diseased leaves have more oxidase than healthy ones and no longer transport starch." Cf. Bul. Col. Agr., Tokyo, Vol. IV, No. 4.

Conditions, such as the abundance of soluble manures, favoring too rapid growth, are very favorable to the disease. The application of nitrogenous or other quick-acting manures does not cure the disease, but intensifies it. This is also the case in the mosaic disease of tobacco.[a] All of the evidence in this case, therefore, points to a condition in the cells of the diseased mulberry very much like that in the mosaic disease of tobacco, tomato, potato, Phytolacca, and other plants. In the case of the mulberry it appears to be demonstrated beyond a doubt that the trouble is primarily due to growth, with an insufficient supply of elaborated nitrogen as available food. Under these conditions there should be found in the diseased mulberry an accumulation of oxidizing enzyms, which in part by their action on the diastase of the cells inhibit the translocation of starch or its transformation into sugar and proteids, thus serving to intensify and fix the disease in the plant.

It thus appears that *whatever causes the reduction of available nitrogenous reserve food, especially soluble nitrogen, below the requirements of dividing cells may cause this disease in the tissues in question.* All of the cases of the disease in tobacco and other plants produced by cutting back severely can be thus explained. We have also a pathological condition of the same nature produced by sucking insects and mites in the young growth of carnations and other plants. Large quantities of reserve proteids and sugars are thus removed, the oxidizing enzyms increase, and the growing cells lose their chlorophyll and finally die. I have described these changes under the name of stigmonose of carnations.[b] The occasional appearance of the disease, as before mentioned, in the young leaves produced at the time of the development of flowers can be explained in this way, as can also the development of the disease in suckers forming on rapidly growing plants.

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[a] Loew, l. c., p. 26.

[b] Bul. No. 19, U. S. Dept. Agr., Div. Veg. Phys. and Path.

The disease is often produced by repotting the young, rapidly growing plants or by transplanting them. At first it was thought that this was due in some way to possible infection from diseased plants, but the work of the past year under conditions free from any possible infection has demonstrated that the trouble can often be induced simply by repotting or transplanting. A rapid root development is induced by this process and it is likely that the reserve nitrogenous food for the terminal growing bud of the stem may be sufficiently reduced to start the trouble. The continuation and intensification of the disease after it is once started is probably to be explained by the action of the oxidizing enzyms, as before pointed out.

INFECTIOUS NATURE OF THE DISEASE.

The apparently infectious nature of the malady is, however, difficult to explain in accord with the facts presented unless the oxidizing enzyms artificially introduced into the plant have the power of inaugurating changes like these described. In my former paper in the Centralblatt f. Bakteriologie, already cited, I pointed out the conflicting results of my first inoculation experiments. I did not at that time obtain infections with the juice of diseased plants filtered through porcelain; and the results obtained by inserting pieces of diseased tissue, healthy tissue, and simple wounding were also apparently conflicting. In one experiment, for example, the disease was produced by inserting a piece of healthy leaf into the stem of a healthy tobacco plant below the terminal bud; in another case the disease developed by simply splitting the stem, without inserting any tissue, while in two cases where diseased tissue was inserted the plants remained healthy. In another experiment the disease was produced by injecting a sterile water solution of peroxidase (obtained by alcoholic precipitation from the juice of a healthy plant) into two young shoots of another healthy plant. These shoots became very severely diseased and distorted, while other shoots on the same plant, as well as those on control plants treated in the same way with distilled water, remained perfectly healthy.

During the past year, however, the results have been less conflicting, and I have come to the conclusion that the failure to produce the disease in some of my former experiments was due to the fact that the diseased tissue was not inserted close enough to the base of the terminal bud. In a recent experiment 100 seedling plants growing in the seed bed were selected. They were about 6 inches high and had from 6 to 8 leaves well developed. All were perfectly healthy. Fifty of the plants were from seed which had been produced by artificial self-pollination, and 50 from seed by artificial cross-pollination. The inbred plants were of light color and the cross-bred of darker green color. So far as determined, inbreeding had nothing to do with the production of the light color. Ten plants (5 each of the light and dark sorts) were selected and their stems split just at the base of the terminal bud; 10 (5 light and 5 dark) were split in the same way and a piece of minced terminal bud from a healthy plant inserted in each, and 10 (5 light and 5 dark) were split and a piece of minced diseased bud inserted in each. In eight days all of the 10 plants infected with diseased material developed violent cases of mosaic disease; not any of the other plants showed signs of the disease at that time. One week later, however, 8 of the 10 plants in which the healthy tissue was inserted were affected, though not so severely as where diseased tissue was used. Not any of the plants which simply had their stems split with the sterile scalpel developed the disease. All were grown to maturity without transplanting. None of the controls developed the disease, and none of the diseased plants recovered, though all produced a few flowers and seed. The plants were fed with nourishing solutions, but did not grow large on account of being too close together. It should be especially noted that, though they were growing so close together that their roots were interwoven, the disease did not spread to the healthy plants. This agrees with field observations, where the plants are often found in pairs, one healthy and the other diseased.[a]

The next experiment was with similar plants from seed out of the same pods as in the experiment above described. There were 30 controls and 30 plants operated upon. They were growing in 3-inch pots and had from 6 to 8 leaves at the time of the experiment. All were healthy. The value of the results was interfered with by the use of lime on the bench under the pots to drive away slugs. Some of the plants were so badly injured in this way that they died. One important point was thus determined, however, namely, that the lime in this case had no effect, one way or the other, upon the development of the disease as the result of inoculation. Injection of unfiltered diseased juice into the terminal bud produced the disease in eight days in 4 out of 5 of the plants treated. The other plant was killed by lime. The disease was also produced in 3 out of 5 cases by pouring the diseased extract on the roots at the base of the stem. The other 2 plants of this series were killed by lime. Boiled diseased juice also produced the disease in 2 out of 5 cases when inj cted into the growing plant. The other 3 plants were killed by lime. Boiled diseased juice also produced the disease in 2 cases in eight days when poured on the roots. The other 3 plants were killed by lime.

ZYMOGEN FOR OXIDASE AND PEROXIDASE.

The boiled diseased juice just mentioned stood eighteen hours at 60° C. before use. This temperature for the time mentioned does not injure the oxidizing enzyms, but prevents bacterial development. It was tested immediately after boiling and found to be free from the enzyms in question. The next day after the injection experiments the remaining portions of the boiled juice were tested and to my surprise gave a strong reaction for both oxidase and peroxidase; in fact it was scarcely weaker than the reaction of the unboiled juice. This at once suggested the possibility of a zymogen for these enzyms. Upon further study, this supposition was found to be correct. In the leaves of tobacco themselves and in the unfiltered extracted juice both enzyms are regenerated in two hours after boiling. A second boiling after four hours is not followed by a regeneration of the enzyms. It is evident, therefore, that the zymogen exists in the cell in sufficient quantity to regenerate practically the same amount of active enzym as is already in the cell. The transformation of the zymogen into the active enzym takes place whenever the active enzym in question is removed or destroyed. The relation of the active and the reserve enzym is evidently a balance not controlled by the protoplasm, as the regeneration occurs in cells which have been killed, but of course no new supply of zymogen is manufactured in such cases, even in expressed juice or in the cells of the dead leaf. The zymogen becomes active only in proportion to the decrease of active enzyms present in the cells at the time they were killed. All of the experiments, therefore, with boiled juice, where it was intended to destroy the enzyms, must be looked upon as simply experiments with the attenuated enzyms, or more correctly, perhaps, an enzym solution of half the strength of unboiled juice.

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[a] Loew, l. c., p. 26.

In the remaining 10 plants in the experiment above referred to, those injected with healthy juice became diseased in 2 cases, 2 remained healthy, and 1 was killed by lime.

Where the juice of the healthy plants was poured on the roots, 2 cases of the disease were produced, 2 remained healthy, and 1 was killed by lime. Five of the control plants were injected with distilled water, but none of them developed the disease. Of the remaining 25 controls, 4 were affected with the disease without any apparent cause.

On the whole, this experiment indicates that there is something in the juice of normal tobacco plants which can, under certain conditions, cause a development of this disease. There is a strong indication in the experiment just described that this substance may be an oxidizing enzym.

In another experiment 24 plants were selected. They were 6 to 8 inches high, had 4 pairs of leaves, and were growing in 3-inch pots, all being perfectly healthy. Of these, 4 were injected in the terminal bud with distilled water, 4 with double-boiled diseased juice free from active or reserve enzyms, 4 with a water solution of oxidase and peroxidase obtained by alcoholic precipitation from the juice of diseased plants, and 4 with unboiled diseased juice; there were 8 controls.

In nine days all the plants injected with solution of the precipitated enzyms, and those with unboiled juice, showed the disease decidedly in their young leaves. Examination the day previous showed in some cases an indication of disease, but it was not sufficient to make the diagnosis sure. The suddenness of the appearance of disease on the ninth day in the two sets of plants is quite remarkable. All of the other plants were at this time apparently perfectly healthy; five days later, however, 2 of the plants injected with distilled water, 1 of those injected with double boiled juice, and 3 of the 8 controls became diseased. All of the plants were carefully repotted three days after the experiment was started. This was made necessary because the roots were coming through the bottom of the pot. This last attack of the disease can probably be attributed to the repotting, which, I have before pointed out, is often alone sufficient to cause the disease to develop. These cases among the control plants were not so severe as those produced by inoculation, but were not otherwise different.

No more cases developed in these plants. They were allowed to go on and fruit without further repotting. The evidence again points strongly toward the enzym as an active agent in bringing on the disease as the result of inoculation. As I pointed out in a former paper, the so-called peroxidizing enzyms remain for a long time active in soil containing the decaying roots of tobacco and other plants. The enzym is freed through the process of decay. Beijerinck and others have shown that soil in which diseased plants have been growing is very favorable to the development of the disease in later crops. An experiment was planned to test infection in this manner. Four 7-inch pots, 2 with mature healthy and 2 with mature diseased plants, were selected. The tops were cut off in each case and all the small roots broken up and mixed with the soil from which they were taken. Some well-rotted cow manure was added to each pot. Healthy young plants were then taken from the seed bed with sufficient earth so as not to disturb the roots and were set, 2 in each pot. The plants had only 2 leaves besides the cotyledons, so it was possible to move them without disturbance. This first series, with 1 healthy control pot, was kept in the laboratory, and the amount of light the plants received was very small compared with what they would have received in the greenhouse. Besides the above, 2 similar pots of diseased plants and 2 of healthy were selected and the tops and taproot were removed in each case, but the soil was not otherwise disturbed, and no manure was added. As controls, 2 pots with fresh soil mixed with manure were prepared, and young plants were set in the same way. This last series was kept in the greenhouse, except 1 of the controls, which was added to the series in the laboratory. Besides the young plants transplanted, 5 fresh tobacco seeds were planted in each pot of both series, all of these seeds coming from 1 pod of a healthy plant. The transplanted plants grew a little faster than those remaining in the seed bed, probably because they were less crowded. The plants in the laboratory grew very slowly compared with those in the greenhouse. After they had grown for a week a sharp scalpel was thrust into the soil near the stem, so as to cut some of the roots of 1 plant in each pot of both series. In the 4 pots in which the diseased roots were present the plants with roots cut developed the disease in eight days after cutting. Those with uncut roots became diseased one after another, until in three weeks all of them were affected. Four weeks from the time of planting the plants with roots cut, growing in soil containing healthy roots, became diseased, and 2 of the plants which did not have their roots cut became diseased a week later. The 2 remaining with roots uncut also finally became diseased. The plants growing in control soil not containing decayed roots remained healthy. The seed sown in the pots nearly all germinated and grew well, especially in the greenhouse. In the laboratory series containing minced roots of diseased plants, one seedling developed the disease in the first leaf after the cotyledon. None of the other seedlings showed any signs of the trouble at this time. This plant, with a healthy one growing near it, was dug up, and 1 of the principal feeding roots of the diseased plant was found growing lengthwise through a piece of decaying diseased root. The roots of the healthy seedling were not in connection with any piece of diseased root in the soil. A test of the soil water, however, indicated the presence of peroxidase, though not in large quantities. The young root growing through the diseased decaying root must have absorbed much more peroxidase than would have been possible if it had not been connected with the decaying root. The diseased piece of root was removed, and was found on examination to be rich in peroxidase. Both plants were again planted, but the diseased plant did not recover.

In the greenhouse all of the 5 seedlings in 1 of the pots in which a diseased plant had been growing (the soil remaining full of decaying roots) became diseased in the first pair of leaves after the cotyledons. In the other pot containing diseased decaying roots 3 of the seedlings were diseased and 2 were healthy. In the pots containing healthy decaying roots 3 seedlings in one and 2 in the other became diseased in the fourth pair of leaves. Seedlings in fresh soil remained healthy.

In the laboratory no more cases of the disease developed in any of the seedlings for several weeks. The plants, however, made a slow growth, owing to the lack of sufficient light. After some time cases began to develop in all the pots containing decaying roots, and finally the 2 plants which had been transplanted to the fresh soil also became diseased. All of the plants in all the pots in the laboratory finally became diseased except the 4 seedlings in healthy soil. None of the plants in the laboratory are flowering, and all are unable to support their weight, falling down over the sides of the pots.

This evidence, along with that gathered from natural-sown seedlings, leads to the conclusion that the presence of decaying tobacco roots in the soil favors the development of the disease. The diseased roots are the most active in producing it, but the healthy roots also seem to favor its development. Whether this is due to the peroxidase set free in decay or to some other active substance can not be definitely decided. The direct infection experiments with this enzym, however, lead me to the hypothesis that it may be absorbed directly by young roots and thus serve, as in the case of hypodermic injections, to start that series of changes which results in the disease. It thus appears that the enzym obtained from either healthy or diseased plants is able, under the proper conditions, to produce the disease. There is no evidence that the peroxidase of the healthy and diseased plants is different, except that the latter is more active, both in the plant and out of it.

The evidence which I have collected, taken along with that obtained by other workers, especially Mayer and Beijerinck, is therefore very strongly in favor of the infectious nature of the trouble under certain conditions. The matter can not, however, be considered as settled. So far as the evidence at hand goes it appears that in growing cells there is possibly a definite relation between active oxidizing power, through the medium of oxidizing enzyms and the availability of reserve food to the growing cells. It appears that this balance between the oxidizing enzyms and the availability of reserve foods can be broken by removing on the one hand the supply of reserve foods, in any way during growth, in which case the enzym content of the cell is increased from two to four times the normal activity. This removal of reserve food may be either the result of diversion to other parts of the plant or by direct removal, as in the case of sucking insects, and possibly also can be brought about by other conditions not at present understood. The same pathological symptoms may therefore be brought about by very diverse causes. On the other hand, the most remarkable thing is that the introduction of the enzyms in question sets up the same series of pathological changes as is brought about by the removal of reserve food, namely, the increase of the normal enzyms of the cell, and the decrease of availability of reserve foods. When this pathological condition is reached it is very difficult for the plant to correct the trouble. The oxidizing enzyms probably move from one part of the plant to another, though how much of the general spread of the disease in the plant is due to such movement has not been determined.

The evidence of the communicability of this disease is quite as strong if not stronger than that upon which rests the belief in the communicability of ordinary variegation through grafting variegated on healthy plants. The two groups of diseases are at least very closely related and are probably simply different phases of the same malady. Possibly peach yellows, as suggested by Smith, and the California vine disease belong here also and are to be similarly explained. Die-back of the orange may also be a related malady. A new disease of the vine, recently described as Le Court-Noue[a] by Professor Ravaz, shows all of the characteristic symptoms of a mosaic disease in marking of foliage, general stunting and deformity of leaves and branches, and transmission by grafting.

In a recent bulletin[b] I called special attention to the fact that plants rich in oxidizing enzyms were more sensitive to unfavorable conditions of temperature, moisture, and especially to insect enemies than plants poor in these enzyms. Some of the reasons for this greater sensitiveness I have already pointed out in this and other papers.[c] All through the work this observation has been confirmed not only for insect and animal pests, but for several kinds of fungi, especially the spot disease of tobacco and spot of violet. Czapek[d] has demonstrated a relation of oxidizing enzyms to geotropic curvature in root tips of several genera of plants. In the most sensitive condition of the young roots there is present, especially in the root tips, an oxidizing ferment and a reducing substance. As the root is stimulated to curve the reducing substance is increased in activity and the oxidizing enzym is reduced in its action.

This work of Czapek's suggests the possibility that there may be a relation of this kind between oxidizing and reducing substances in plants sensitive to parasites of various kinds, especially as I have already shown that sensitive individuals are rich in the oxidizing ferments. This presence of reducing substances is indicated in many of the preliminary tests, but their exact nature has not yet been determined. It appears quite likely that resistance to parasitic attack may be correlated with decreased irritability; or, what amounts in many cases to immunity may be brought about in the plant or animal by the development of these reducing substances. A further study of their relations in this connection is in progress in the laboratories under the writer's direction.

PREVENTIVE MEASURES.

The writer has not had opportunity, on account of other work, to go into the question of preventive measures under field conditions, to any great extent. The first work was to determine the nature and causes of the disease, the second step is to determine the remedy. In this inquiry the following facts must be remembered:

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[a] L. Ravaz. Progres Agricole et Viticole, Nos. 21 and 24, 1900.

[b] Bul. 19, U. S. Dept. of Agr., Div. Veg. Phys. and Path.

[c] Physiology in Relation to Agriculture. Bull. 99. U. S. Dept. Agr., Office of Expt. Stations.

[d] Berichte d. d. botan. Gesellschaft, Bd. XV, pp. 516-520, 1897.

The disease is not due to parasites of any kind, but is the result of defective nutrition of the young dividing and rapidly growing cells, due to a lack of elaborated nitrogenous reserve food accompanied by an abnormal increase in activity of oxidizing enzyms in the diseased cells. The unusual activity of the enzym prevents the proper elaboration of reserve food, so that a plant once diseased seldom recovers. On the decay of the roots, leaves, and stems of both healthy and diseased plants, the enzym in question is liberated and remains active in the soil. The enzym is very soluble in water and appears to pass readily through plant membranes. If young plants take it up in sufficient quantity to reach the terminal bud, they become diseased in the characteristic way. Under field conditions there is little danger from infection in this manner, but in the seed bed the danger is much greater on account of the greater susceptibility of the young plants to disease, and the greater amount of free-oxidizing enzyms likely to be in the soil, due to the decay of roots and plants. New or steam-sterilized soil should therefore be used for the seed bed.

I have shown that transplanting, especially when the roots are injured, may produce the disease. Great care must therefore be taken not to injure the roots in this process or in subsequent cultivation, or to check the growth of the plants.

There is evidence that rapid growth, caused by too much nitrogenous manure or too high temperature, is favorable to the disease. Why this should be the case has not been determined. It is probably connected, however, with the manufacture of reserve nitrogen by the cells and its distribution to the rapidly growing parts.

Plants grown under such conditions are less able to stand successfully marked variations in temperature and moister conditions of soil and atmosphere. Variations of this kind favor the development of the disease in the less resistant plants.

Close clayey soils, packing hard after rains and requiring constant tillage, are not favorable to even growth of either the tops or the roots of tobacco plants. In moist, cloudy weather the plants will grow too fast, and in hot, dry weather the soil is likely to bake, checking growth and making probable injury to the roots in cultivation. Such soils are very favorable to the development of mosaic disease, as pointed out by Thaxter.[a] He found that loosening the soil by liming and giving partial shade, thus causing a more even condition of growth, very greatly reduced the amount of disease. The following table is taken from his report. It shows the percentage of "calicoed" plants on each plot, shaded and unshaded. "Calico" was very prevalent in all of the tobacco fields in the neighborhood.

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[a] Conn. Report, 1899, III, p. 253.

Effects of liming and shading on development of mosaic disease.

Plat.	Amount of lime used.	Diseased plants on unshaded portion.	Diseased plants on shaded portion.
	Pounds.	*Per cent.*	*Per cent.*
I	300	10	5
II	500	17	2
III	1,000	0	2
IV	2,000	0	0

The plants under the partial slat shade did not grow quite as fast as those outside, but the conditions were, of course, less variable.

Crops grown under cheese-cloth covers protected at the side, thus making even conditions of growth, are said to be remarkably free from disease. The plants make a steady, rapid growth—much greater than in ordinary field culture.[a] The quality of the leaf is pronounced of the highest grade for cigar wrappers.

In the South, wet, poorly drained soil is said to favor the development of calico. This would be expected on the same grounds as suggested above.

Seed should not, on general principles, be saved from plants which develop this disease, though it is not as a rule transmitted in this way. The seed may lack in vigor, and the plants produced from them would be expected to have a tendency to develop the trouble in circumstances favorable to the malady. The experimental evidence on this point is, however, not conclusive.

The disease is not, so far as observed, produced by a lack of soil nutrients, though from its nature we would expect that a deficiency of nitrogen, phosphoric acid, lime, or magnesium might favor its development. Koning[b] says that manuring with kainit and Thomas slag diminishes the extent of the disease. Mayer, Beijerinck, and other investigators, however, agree that the trouble is not caused by the lack of any soil nutrients. It appears, so far as my own investigations go, that the trouble can not be cured by giving the plants additional food of any kind. Overfeeding with nitrogen favors the development of the disease, and there is some evidence that excess of nitrates in the cells may cause the excessive development of the ferments causing the disease. Very slight attacks of the disease known as mottled top are said not to injure the quality of the leaf to a sufficient extent to be noticeable commercially, though they are less elastic and have a poorer burn and aroma than healthy leaves.

It is hoped that the observations brought together in this paper may at least help those who are investigating this trouble to solve the problem of its control.

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[a] See Report 65, U. S. Dept. of Agriculture.

[b] Zeitschrift für Pflanzenkrankheiten, 1899, p. 65.

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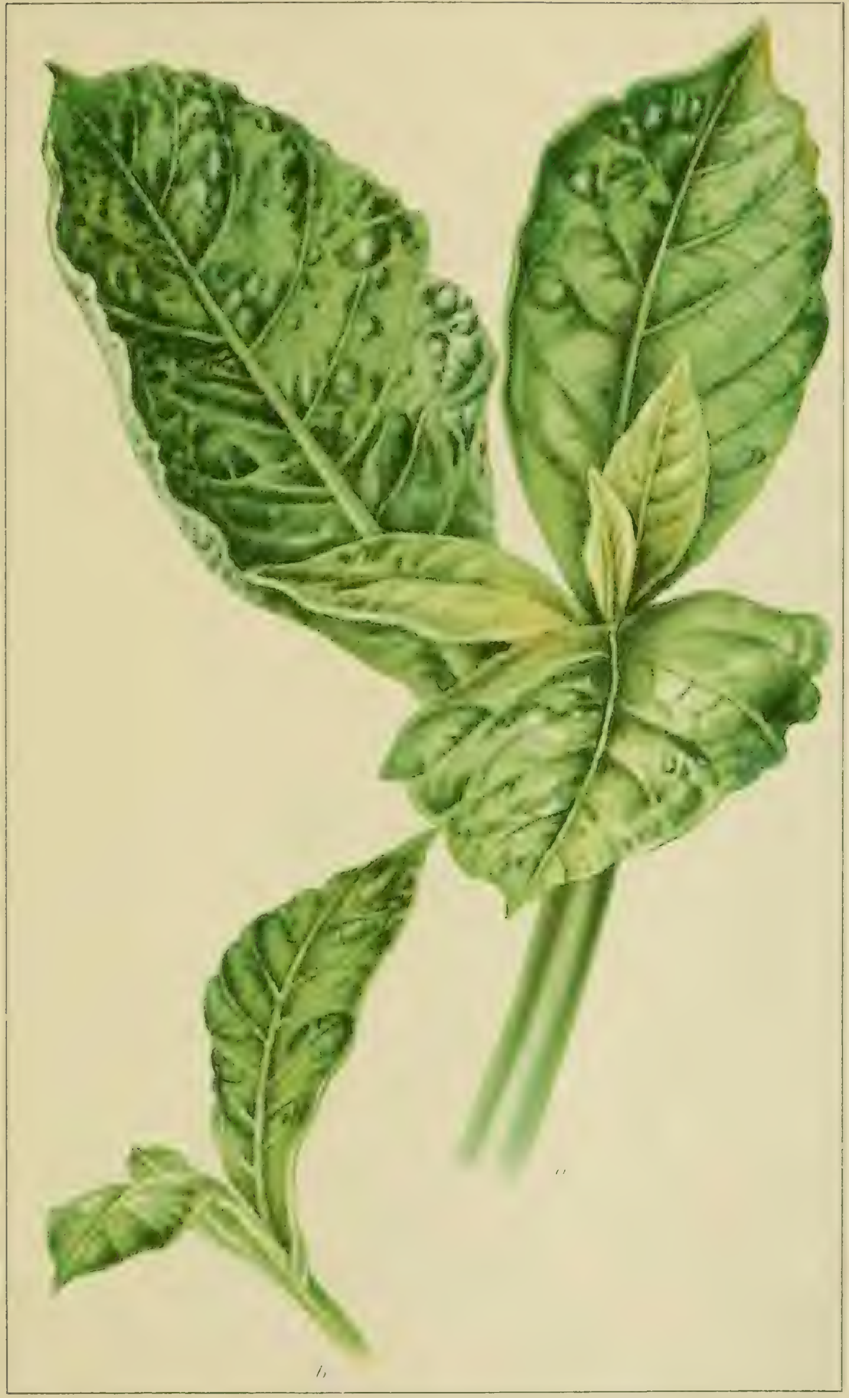
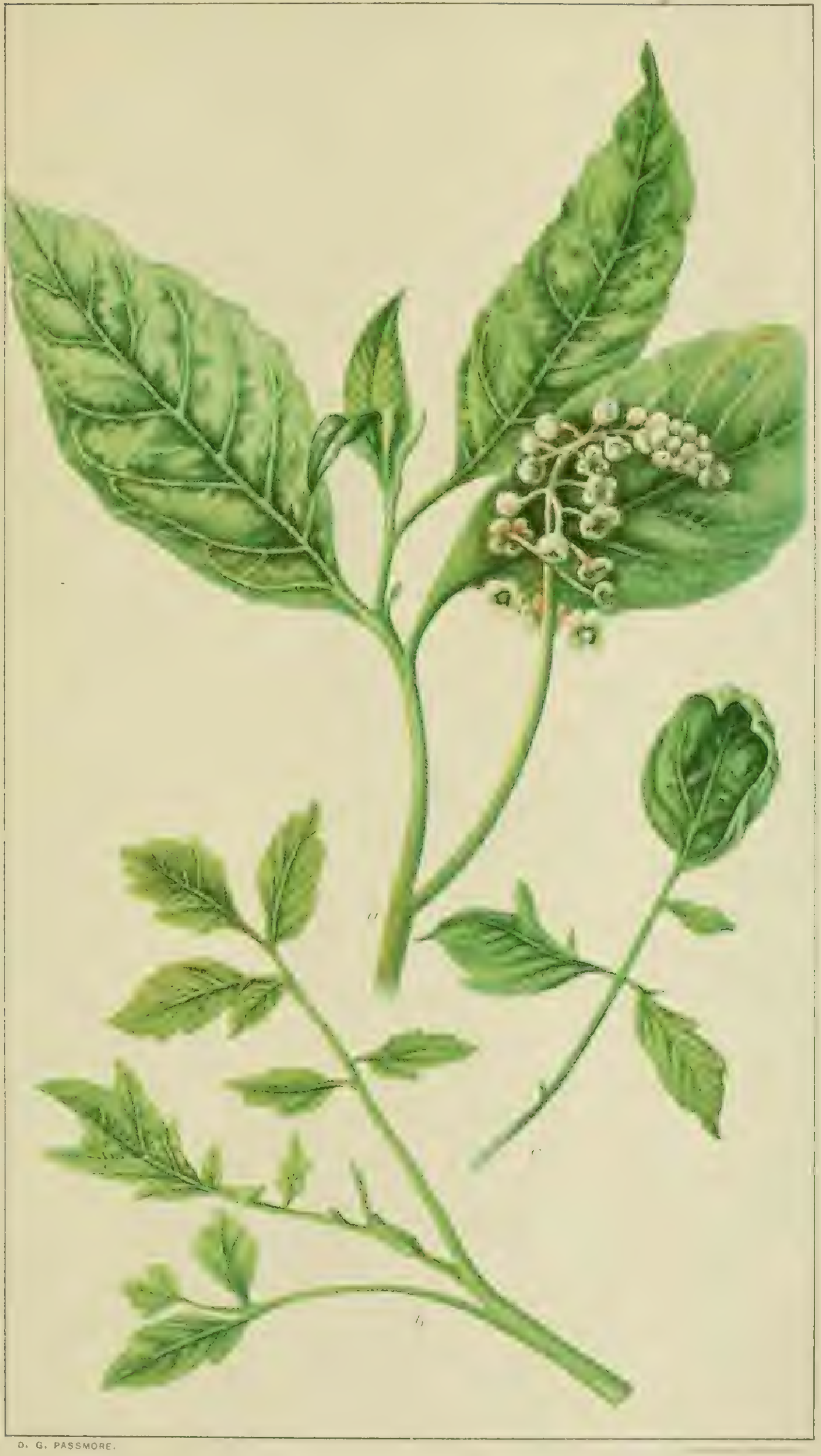


D. G. PASSMORE.

MOSAIC DISEASE OF TOBACCO:
(*a*) NATURAL DISEASE ON SUCKER. (*b*) DISEASE PRODUCED ON YOUNG PLANT BY CUTTING BACK.

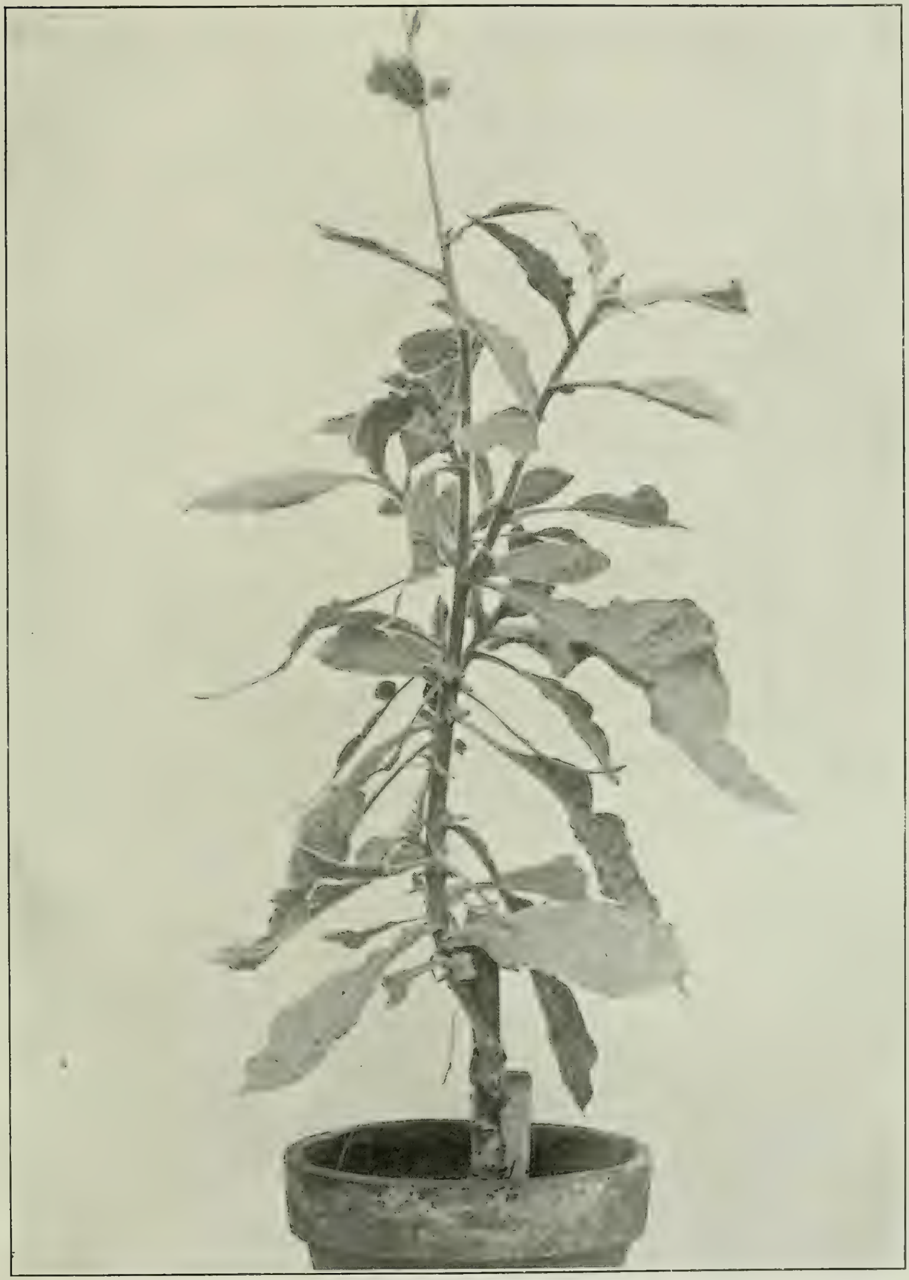


D. G. PASSMORE.

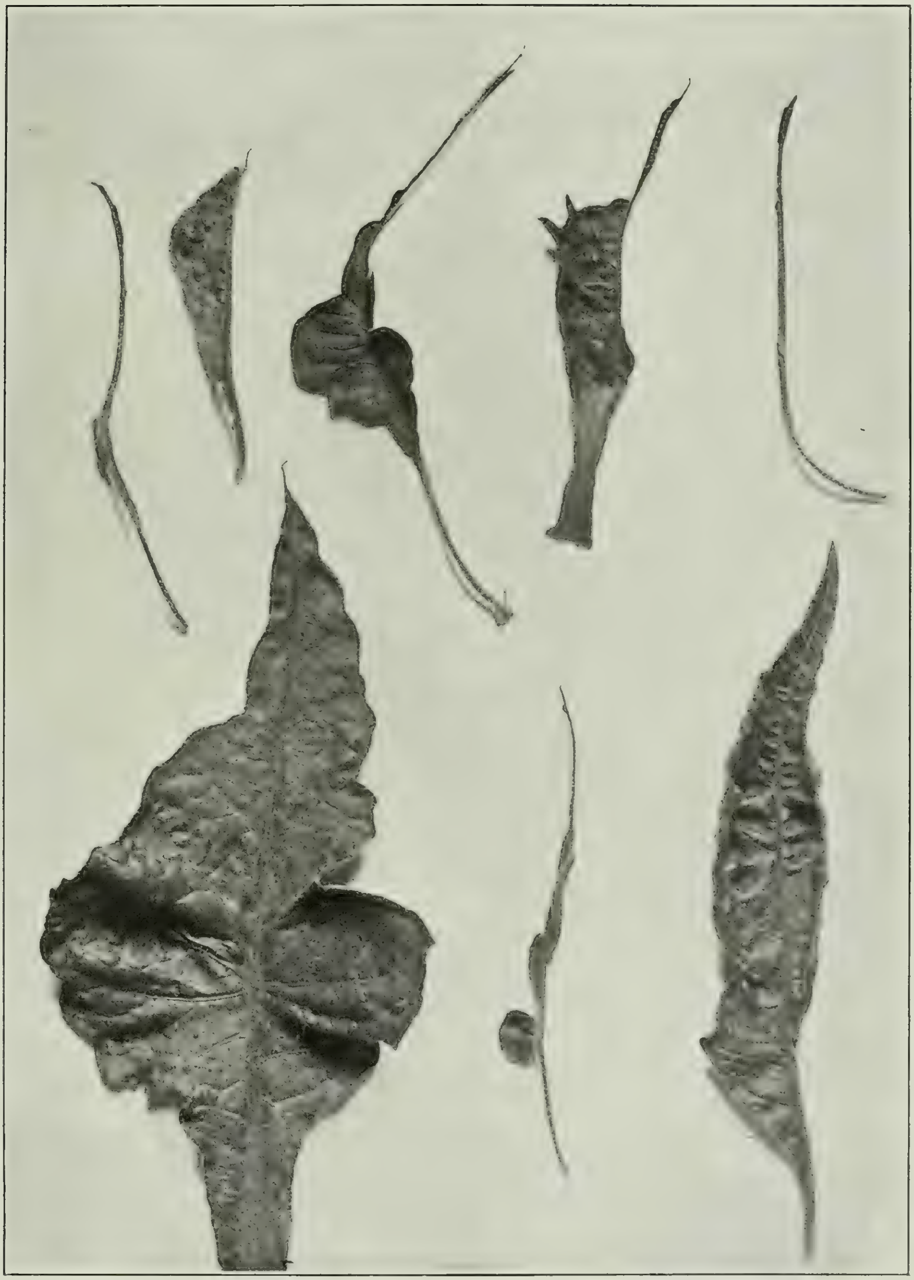
MOSAIC DISEASE PRODUCED BY CUTTING BACK:
(*a*) POKEWEED, (*b*, *c*) TOMATO.

PLATE III. 3

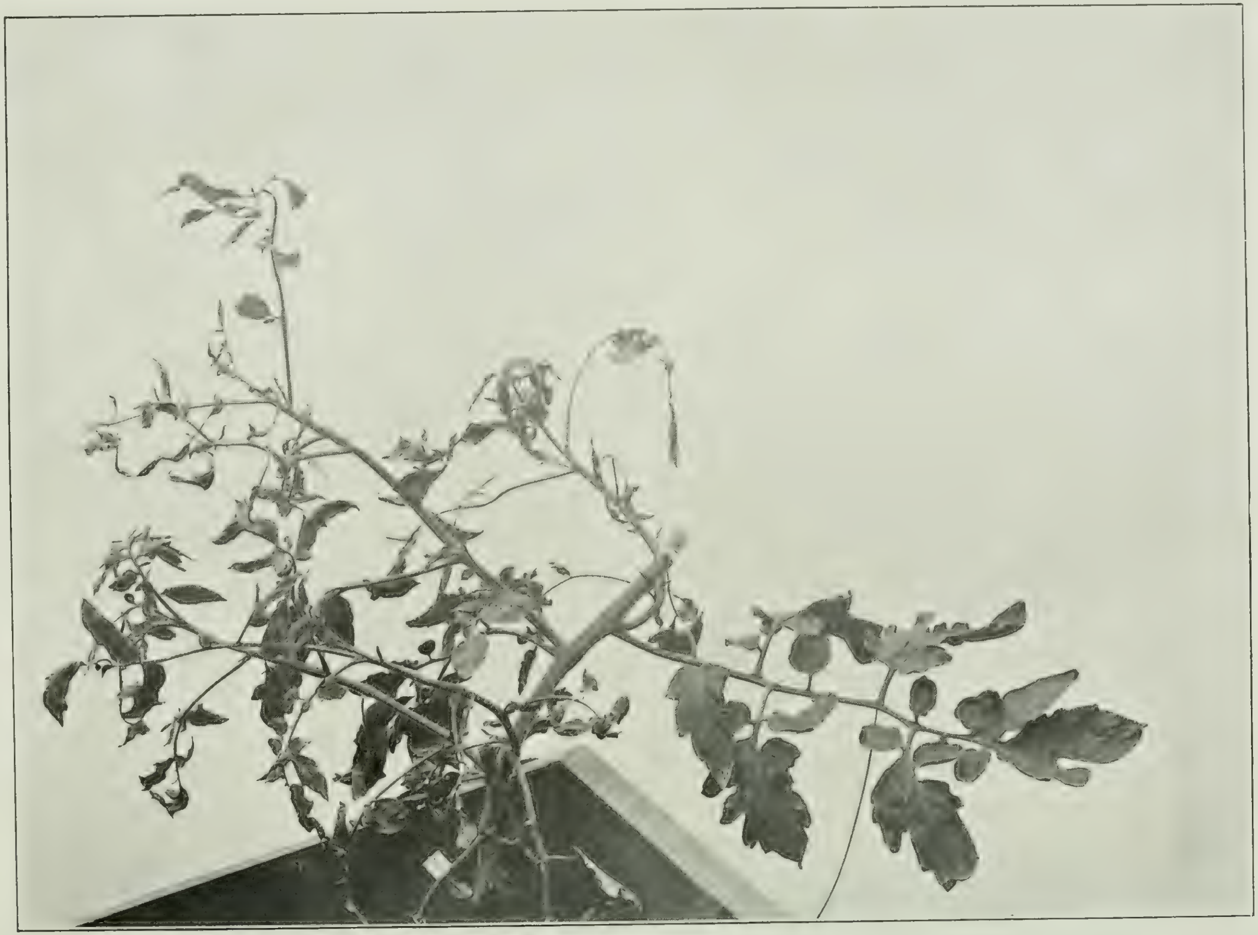
24



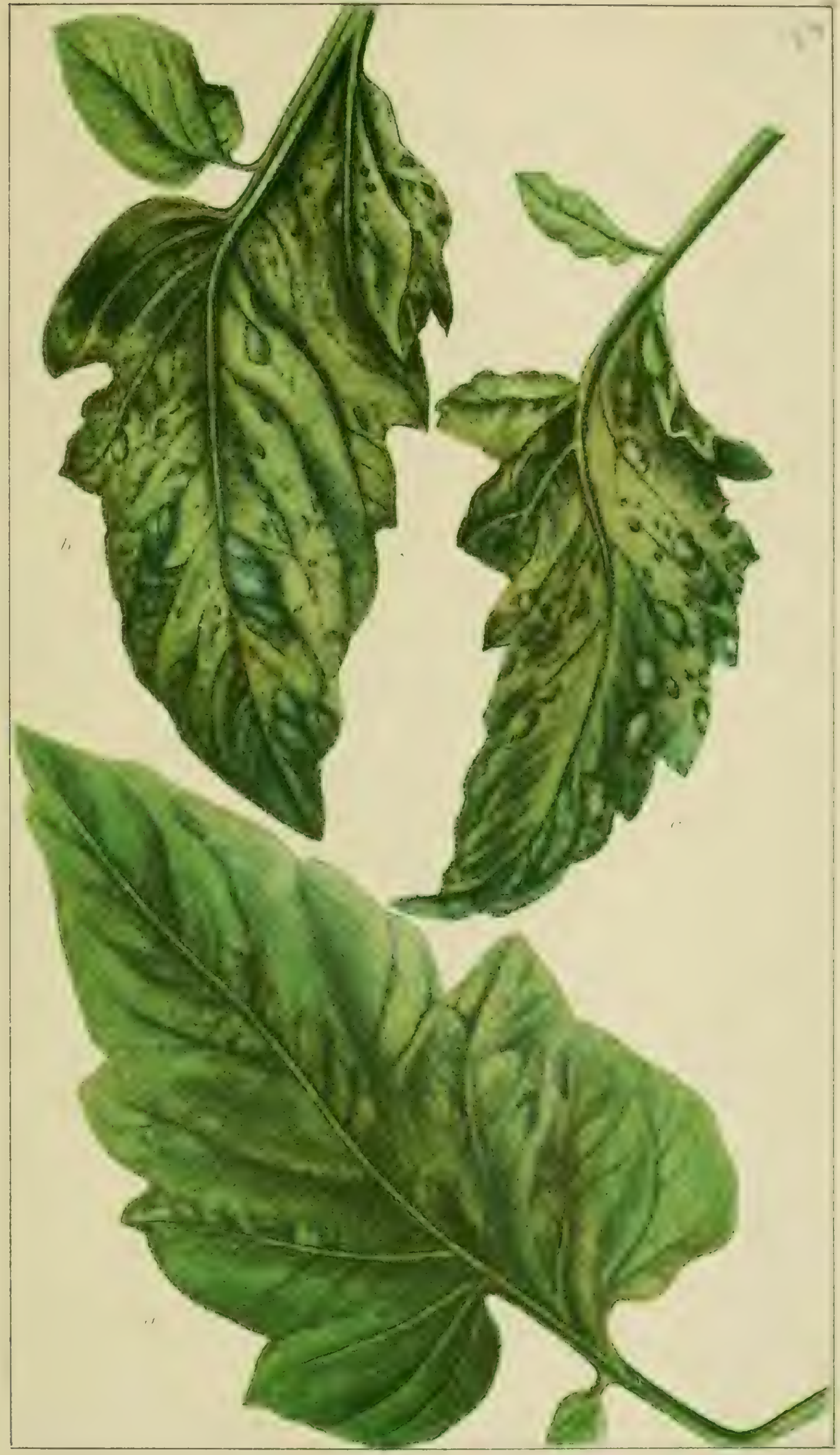
DISTORTION OF TOBACCO FOLIAGE BY MOSAIC DISEASE, CAUSED BY CUTTING BACK.



DISTORTED LEAVES FROM PLANT SHOWN IN PLATE III.



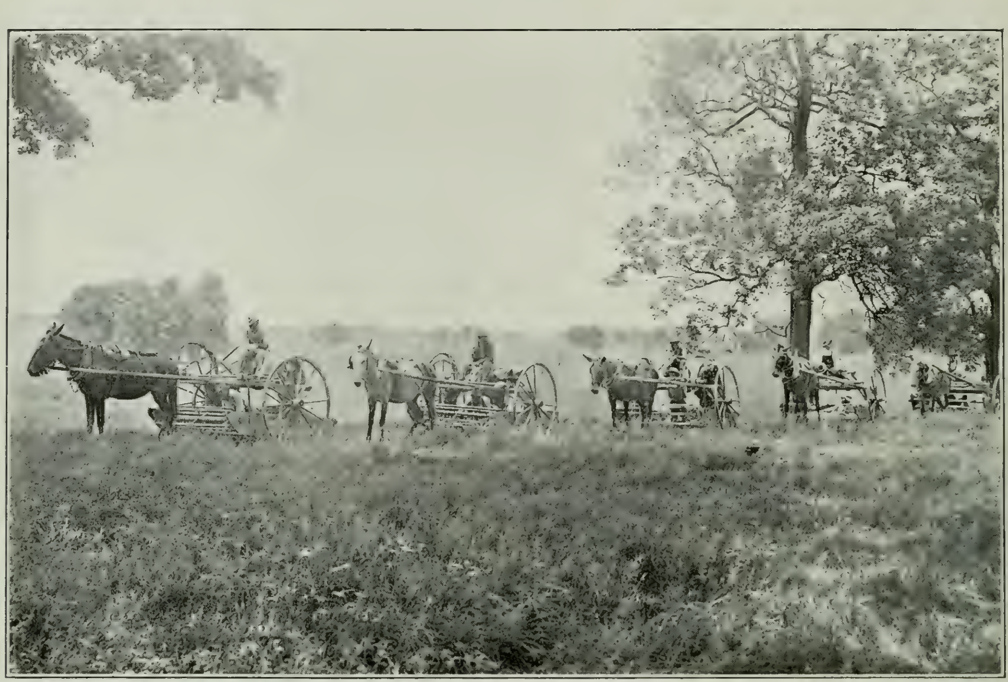
MOSAIC DISEASE OF TOMATO, PRODUCED BY CUTTING BACK. HEALTHY LEAF ON RIGHT.

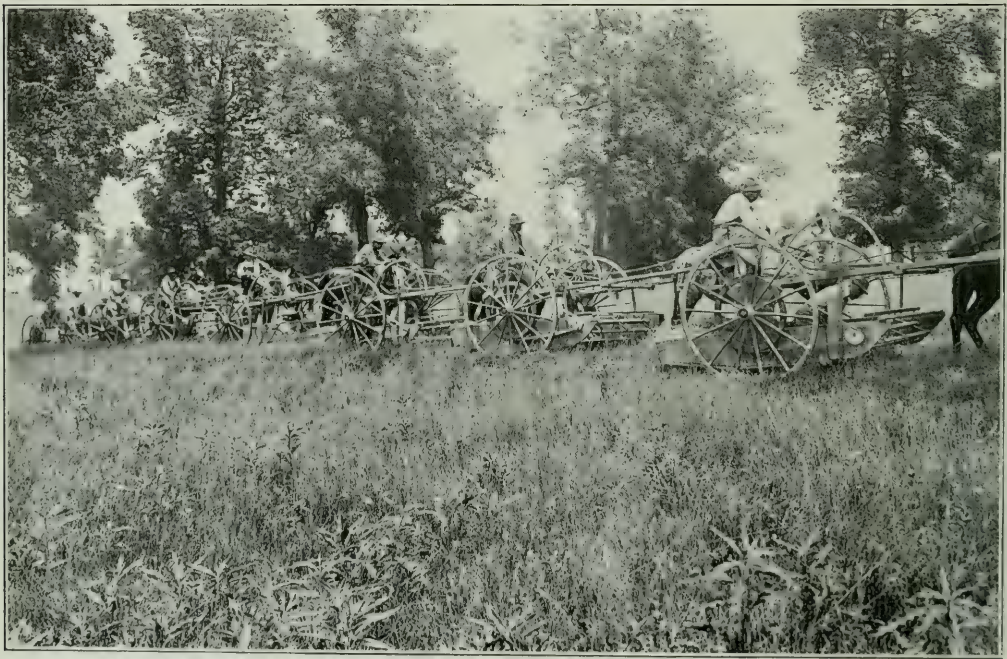


D. G. PASSMORE

MOSAIC DISEASE OF TOMATO:

(*a*) HEALTHY LEAF FOR COMPARISON, (*b* AND *c*) DISEASE PRODUCED BY CUTTING BACK.





STRIPPING BLUEGRASS SEED IN KENTUCKY.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 19.

B. T. GALLOWAY, Chief of Bureau.

KENTUCKY BLUEGRASS SEED:

HARVESTING, CURING, AND CLEANING.

BY

A. J. PIETERS,
BOTANIST IN CHARGE OF SEED LABORATORY,

AND

EDGAR BROWN,
ASSISTANT BOTANIST, BOTANICAL INVESTIGATIONS
AND EXPERIMENTS.

1862 1889

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GOVERNMENT PRINTING OFFICE.
1902.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 30, 1902.

Sir: I have the honor to transmit herewith a paper entitled Kentucky Bluegrass Seed: Harvesting, Curing, and Cleaning, and respectfully recommend that it be published as Bulletin No. 19 of the Bureau series. The paper was prepared by Mr. A. J. Pieters, botanist in charge of seed laboratory, and Mr. Edgar Brown, assistant botanist, both of Botanical Investigations and Experiments, and was submitted by the Botanist.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The seed of Kentucky bluegrass forms an important item in the grass-seed trade of the eastern United States, both in the domestic market and for export. In the absence of precise statistics, it may be stated that the annual crop averages from 200,000 to 300,000 bushels, with a value of $200,000 to $300,000. In the progress of our studies in the seed laboratory a surprising variation was found in the percentage of germination of this seed. It was suspected that the vitality of the seed was injured at some stage in the process of harvesting or curing. An investigation was therefore instituted which has involved an examination, by Mr. Pieters and Mr. Brown, of the field operations of the growers in Kentucky during the harvesting seasons of 1900 and 1901, together with an extensive series of germination tests conducted in Washington. This investigation, the first results of which are herewith published, has demonstrated conclusively that the frequent low germination of Kentucky bluegrass seed is in reality due to improper treatment during the process of curing the crop, which results in overheating the seed and destroying its vitality. The investigation has demonstrated, further, that this overheating is preventable. It is believed that a drying apparatus can be used which will obviate the difficulty and take the place of the expensive hand labor or expensive storage facilities which otherwise are necessary. Further experiments relative to such apparatus are planned for the coming year.

FREDERICK V. COVILLE,
Botanist.

OFFICE OF THE BOTANIST,
Washington, D. C., January 21, 1902.

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KENTUCKY BLUEGRASS SEED: HARVESTING, CURING, AND CLEANING.

INTRODUCTION.[a]

Among pasture grasses there are none that take higher rank than the bluegrasses. Scattered throughout the north temperate portions of the globe, the various species afford, often in great abundance, natural pasturage of the best quality. This is nowhere more the case than in the United States, where a single species, the Kentucky bluegrass (*Poa pratensis*), has made famous one of the most beautiful and richest regions of this country.

DISTRIBUTION OF KENTUCKY BLUEGRASS.

This species is distributed almost throughout North America and is common in the Northeastern and Middle States, but reaches its best development in the rolling country of Kentucky, Missouri, and Iowa. The bluegrass region of Kentucky consists of gently rolling limestone slopes, with every uncultivated rise and hollow covered with a carpet of bluegrass, green in spring and fall and in early summer changing to great brown billows of the grass in seed.

From Kentucky the bluegrass was carried to Missouri and to Iowa, where it is now so well established that it lies at the foundation of the extensive and growing stock-raising industry. The story of how the bluegrass was brought to Iowa is told in Wallace's Farmer, and is worth quoting as part of the history of American agriculture. Mr. Wallace says:

> When we first came to Winterset in 1877 we noticed that the bluegrass was spreading from that town westward, the first seed having been brought to that region many years before by a traveler from Kentucky, who adopted the unique method of paying his expenses by giving bluegrass seed to the settlers.

QUALITY OF SEED REQUIRED BY THE FOREIGN TRADE.

It is well known to the trade that poor seed can not be sold to the European buyers. The foreign market demands not only heavy seed, but seed that will germinate well, and in many of the dealings between American and European firms bluegrass seed is sold at a price proportioned to the percentage of germination. Unfortunately, no such system prevails in the United States, and the domestic trade uses the bulk of the bluegrass seed that has been spoiled by careless handling.

---

[a] The authors desire to express their thanks for the many favors and opportunities for study offered by the growers and cleaners of Kentucky bluegrass seed in and about Lexington, Winchester, and Paris, Ky., and also for the help and suggestions afforded by Professor Scovell, director of the Kentucky Agricultural Experiment Station, and Professor Garman, entomologist and botanist.

ADULTERATION.

Another matter seriously affecting the quality of the seed is the adulteration of Kentucky bluegrass seed with that of Canada bluegrass. These seeds resemble each other closely, and more than one firm, even among those doing business in and near Kentucky, has sold adulterated seed. Canada bluegrass undoubtedly has its place, but that place is where Kentucky bluegrass does not succeed. When the latter is wanted, the Canada seed is worthless or worse than worthless, and the Kentucky farmers have reason for protesting against a practice injurious to their pastures.

SOURCE OF THE MARKET SUPPLY.

The Kentucky bluegrass seed for sale on the American market is all home grown. Although the bluegrass as a pasture and meadow crop has spread over most of eastern North America, the harvesting of the seed is limited to a few localities (fig. 1). The best known, as well as

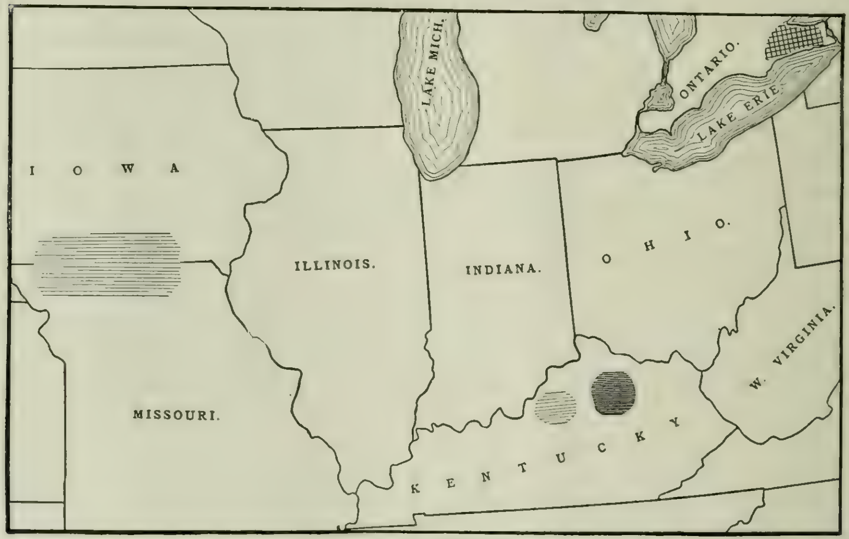

FIG. 1.—Map showing areas in United States and Canada where Kentucky and Canada bluegrass seed are harvested.

▤ The bluegrass region of Kentucky. The bulk of the Kentucky bluegrass seed is harvested from this area.

☰ Areas in which a limited quantity of Kentucky bluegrass seed is harvested.

▦ Area in which Canada bluegrass seed is harvested.

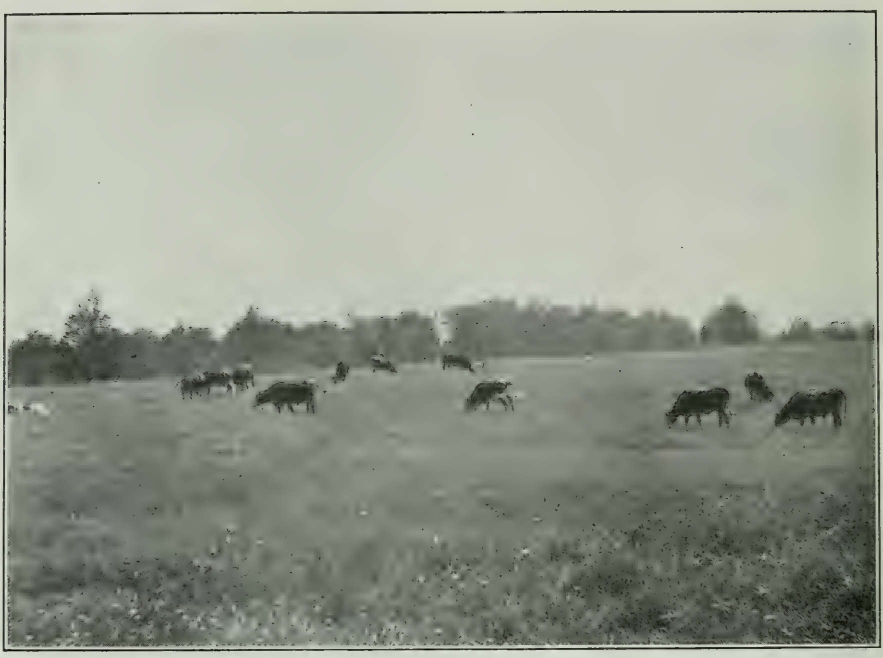

FIG. 1.—CATTLE IN BLUEGRASS PASTURE AT TIME OF HARVESTING.

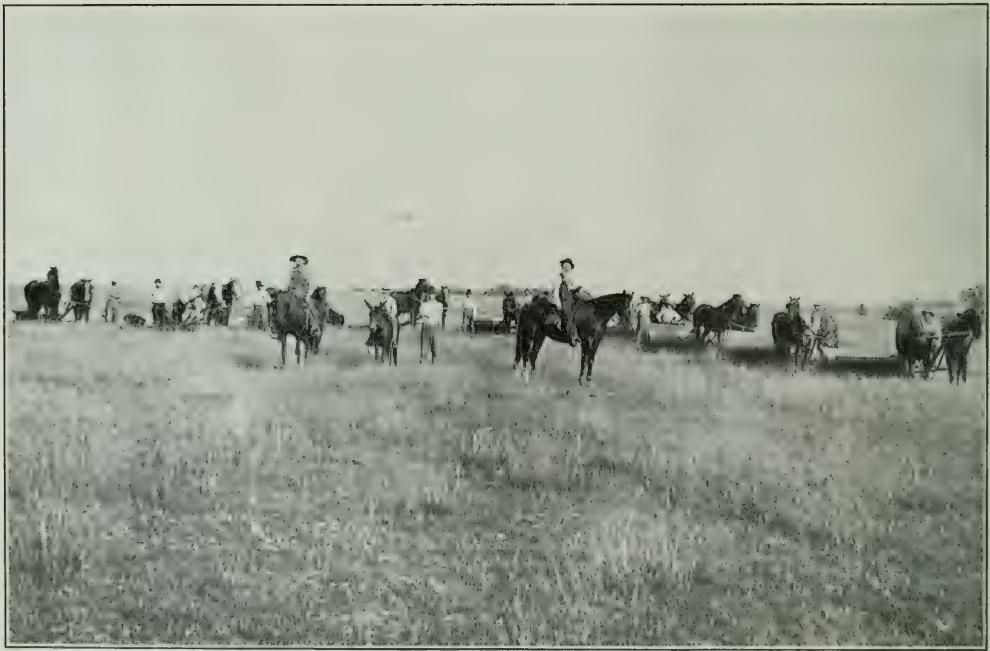

FIG. 2.—STRIPPING BLUEGRASS SEED IN IOWA.

the most important of these, is in Kentucky, where the counties of Bourbon, Fayette, and Clark, in the heart of the bluegrass region, produce the greater part of the seed crop of Kentucky. The adjoining counties of Scott, Montgomery, Woodford, Franklin, and Jessamine also produce some, and small quantities are doubtless harvested in other parts of the State. Most of the seed is secured within a radius of 25 miles from the center of a triangle formed by lines connecting the cities of Lexington, Paris, and Winchester. A few years ago this seed was first harvested in Iowa (Pl. II, fig. 2), where, in 1897, one man gathered 11,200 bushels in Lucas County. Since that time a cleaner has been put up in Creston, Union County, and during 1900 this mill turned out 6,000 bushels of "fancy," all gathered in the vicinity of Creston. Seed is also gathered at points in Missouri, and a little in Illinois.

FACTORS CONTROLLING THE PROFITABLE HARVESTING OF SEED.

The first requisite to profit in gathering the seed is, of course, an abundant growth of the grass, free from other plants. The profitable use of comb strippers is confined to districts having a clay soil. On sandy soil the plants are pulled up. Where rotary strippers are used this trouble is not experienced. Another controlling factor is the location of cleaning mills. Since the market chiefly demands fancy cleaned seed, Kentucky bluegrass seed can not be profitably harvested except within a reasonable distance from a cleaner. At present there are seven cleaners in Kentucky, one being located at Georgetown, one at Lexington, and five at Paris. There is one cleaner at St. Louis, Mo., and at least two at Kansas City, Mo., besides the one previously mentioned as being at Creston, Iowa. Most of these mills draw their supply of rough seed from the surrounding country, but in some cases it is brought to the mills in carload lots.

YIELD PER ACRE AND TOTAL CROP.

The amount of rough seed harvested per acre varies greatly. A good crop is 15 or 20 bushels per acre, while sometimes not more than 2 to 5 bushels are secured, though 25 bushels per acre is not uncommon. The amount gathered depends largely upon the amount of pasturing permitted. Cattle are allowed to graze freely (Pl. II, fig. 1) in the pastures from which seed is to be taken, because so long as they can eat the fresh leaves they avoid the flowers and seeds, although it is now generally recognized by the best growers that it is not profitable to pasture within about two weeks of the time of stripping. Horses, however, will eat the panicles in all stages and can not be permitted in a pasture when a crop of seed is wanted. It is well known in Kentucky that a "horse country" is not a good "seed country," while a "cattle country" produces good crops of seed as well as pasturage.

The total crop in Kentucky is variously estimated at from 300,000 to 600,000 bushels of rough seed, of which about 60 per cent is "fancy grade," the balance being "extra clean" or waste. The crop west of the Mississippi is much smaller, probably not over 25,000 or 30,000 bushels of "fancy;" but no reliable data are available for an estimate.

HARVESTING.

SEASON.

Kentucky bluegrass blooms in the latter part of May and the seed ripens during the second and third weeks in June. The average time for harvesting is about June 10 to 15. If the weather is favorable, the time for gathering the seed may be ten to twelve days, but usually the height of the season does not last more than five days. Stripping usually begins when the panicle is yellow and the culm still green. All the glumes should be yellow, except, possibly, a little green near the base of the youngest. At this time the grain is hard, or at least firm, and the after-ripening will enable it to reach full maturity. As the number of machines (Pl. I) needed by those growers who harvest two or three thousand acres, or even several hundred acres of seed, is large, and as the season is very short, it is not possible to wait until the fields are in the ideal condition before beginning the harvest. If this were done, some fields would become overripe and much of the good seed would be lost by shattering. When the seed is dead ripe, it becomes loosened from the spikelet and is often held by the web alone. In this condition it is readily beaten out by a severe wind or rain storm.

HARVESTING GREEN SEED.

The scarcity of machines, taken together with the competition among the buyers of uncured seed has encouraged the growers to begin stripping before the seed is sufficiently matured. Some bluegrass growers go to the extreme of harvesting the seed while the entire panicle is still green and the grain in the milk. By this means a greater weight is secured, and since all bluegrass seed is bought at the rate of 14 pounds per bushel, a greater number of bushels of uncured seed can be harvested at this time from a given area than if the seed is allowed to ripen. When such seed is cured by the producers this extra weight is, of course, lost; but some who sell directly from the strippers consider nothing but their immediate gain. Such seed heats more while curing than riper seed, does not after-ripen well, and is finally of poor quality, if not actually worthless. The temptation to strip seed too green is increased by the fact that most buyers make no distinction in price between different qualities of rough seed. Some of the larger buyers do, however, refuse to accept seed harvested too green and sometimes pay less for the crop of a farmer whom they know to be careless about curing.

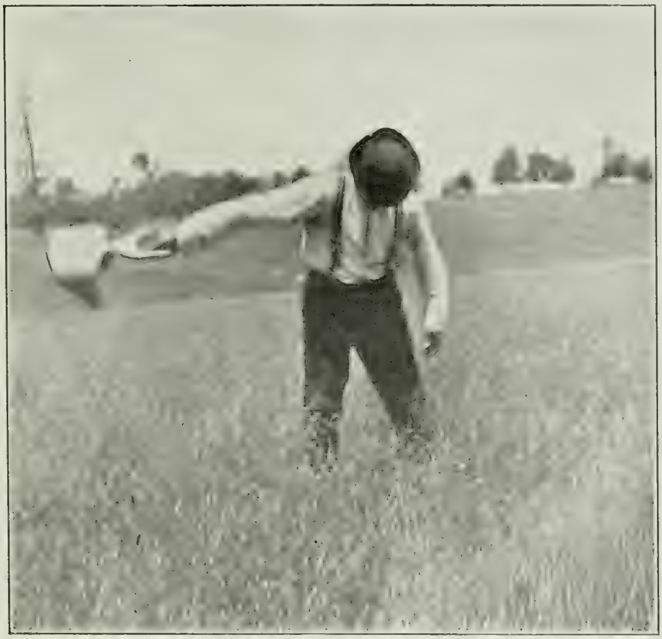

FIG. 1.—STRIPPING BLUEGRASS SEED BY HAND.

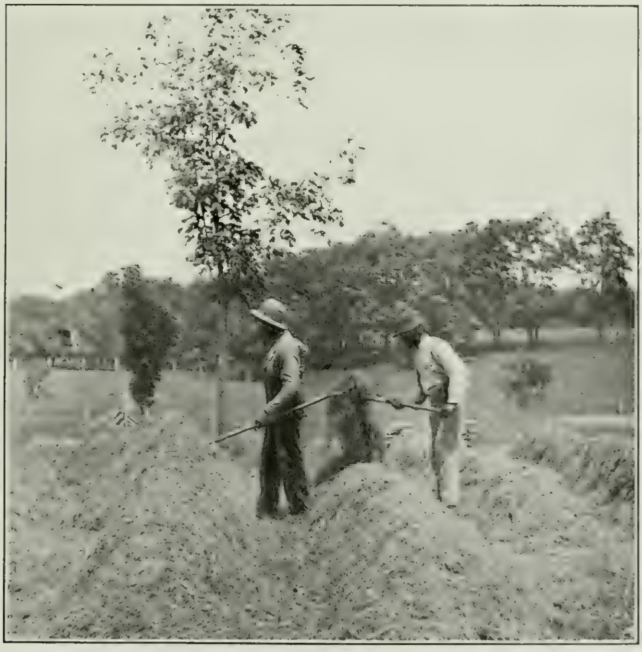

FIG. 2.—STIRRING BLUEGRASS SEED WHILE CURING OUTDOORS.

METHODS—KINDS OF STRIPPERS.

The bluegrass seed is harvested both by hand and by horsepower machines. When Kentucky bluegrass seed was first collected, it was stripped off by hand and rubbed through sieves to clean it. At this time there was scarcely any demand for the seed, and the amount saved was consequently very small. The first improvement was what is known as the hand stripper (fig. 2), which soon became generally used. This stripper consists of a comb made of long, flat teeth set close together on the front edge of a small scoop-like box. The stripper is held in one hand and swung through the bluegrass (Pl. III, fig. 1) and with a dexterous twist is brought up again so that the seed stripped off falls to the rear part of the scoop. It is still used by colored men, women, and children to gather seed along the roadsides, in waste places, and in fields whose owners do not themselves intend to harvest the seed. The seed gathered by hand is brought to the buyers in lots of 1 bushel or more and was formerly the best in the market, but since the industry has been more fully developed the horse machines gather all of the best of the crop and leave little of good quality to be gathered by hand.

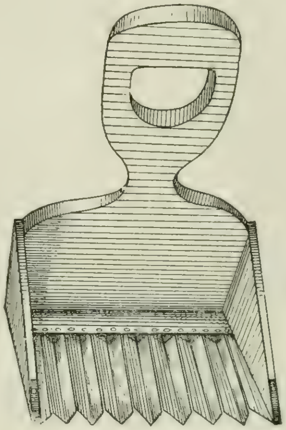

FIG. 2.—Hand bluegrass stripper.

The horsepower machines are of three kinds. The oldest and most commonly used is the comb stripper (Pl. IV, fig. 1), which consists of a platform hung on wheels and armed in front with a heavy steel comb, similar to that used in the hand stripper. The upper surface of this comb is smooth, and when harvesting a laborer kneels on the platform and cuts off the panicles as they are caught by the comb. For this he uses a broad, flat knife (fig. 3), which is passed back and forth over the comb. The stripper, which takes a breadth of between 5 and 6 feet, is drawn by one mule and has arrangements for raising and lowering the platform so as to accommodate it to the height of the grass. Since the culms are not usually of uniform height, much seed is lost, even with the best management. Where there are many weeds, or when timothy is abundant, these strippers can not be used to advantage. When the platform, which has raised sides and back, is full, the seed, mixed with the grass, weeds, and sticks, is put into large burlap sacks to be later hauled to the barn or grounds where the seed is to be cured. As the seed comes from the stripper

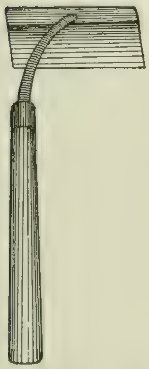

FIG. 3.—Knife used with comb stripper.

only 35 to 45 per cent will make fancy clean seed. Part of this loss is accounted for by the loss of water in curing and part by the chaff and straw taken out by the cleaners.

An improved form of the comb stripper (Pl. IV, fig. 2) has been designed, but only six of them have ever been built. This has an automatic knife for cutting off the heads as they are caught by the comb and an elevator which carries the rough seed away from the comb and drops it into a sack fastened at one side of the machine. When this sack is full the operator takes it off and leaves it in the field to be gathered up by the wagons that follow. The use of this machine makes a great saving of time, as there is no delay required to empty, and one man and one mule can operate it. It will doubtless admit of some mechanical improvement, but seems to work well and economically.

The rotary cylinder form of machine (Pl. V, fig. 1) is of more recent introduction, and is built on very different lines from the comb stripper. It consists of a wooden cylinder which is studded with large iron nails set in spirals, and which is hung in front of a platform upon which the seed is thrown. When in use the cylinder revolves rapidly, and the panicles of the bluegrass are struck by the nails, the seed, together with some straw and weeds, being thrown back into the receiving box. When the box is full the seed is put into sacks and hauled to the barns or curing grounds. With this form of machine it is possible to collect seed on sandy land where the grass would be pulled up by the roots with a comb stripper. Two mules and one man are required to operate it.

All of the styles are in use in Kentucky, but the old comb stripper is the only one at all common.

CURING.

Forty years and more ago, when only small quantities of bluegrass seed were collected, careful gatherers placed the piles of rough seed on large canvas sheets for one or two days during fair weather and finished the curing in the barns. This method is not practicable at present on account of the large quantity of seed harvested.

PRESENT METHODS.

There are two general methods of curing now employed: One may be called the indoor method (Pl. V, fig. 2, Pl. VI, fig. 1) and the other the outdoor method (Pl. III, fig. 2, Pl. VI, fig. 2). In either case the seed, mixed as it is with grass and weeds, is piled in ricks or windrows. These are preferably as low and narrow as possible and of any convenient length. When the curing is done in a building the length of the rick is limited by the size of the building, and consequently when

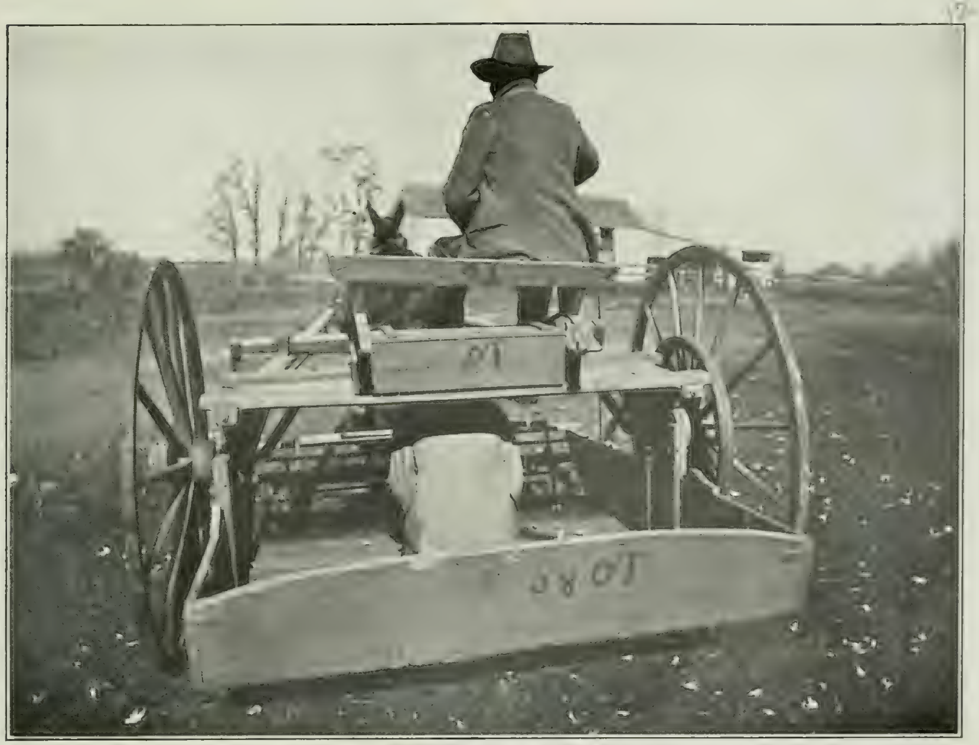

FIG. 1.—COMB STRIPPER, COMMON STYLE.

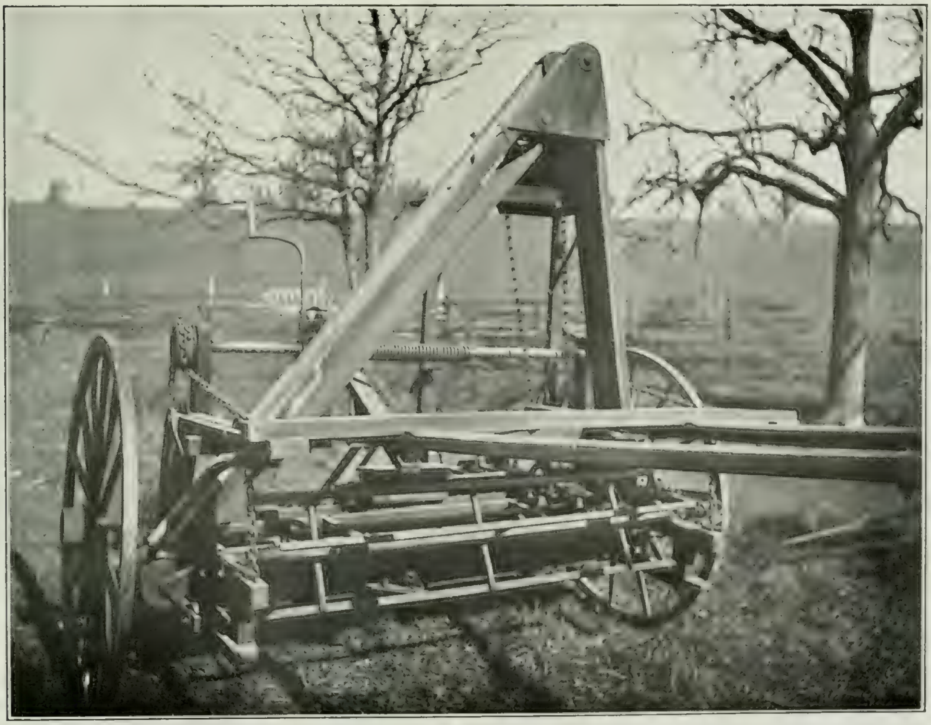

FIG. 2.—COMB STRIPPER WITH AUTOMATIC ATTACHMENT.

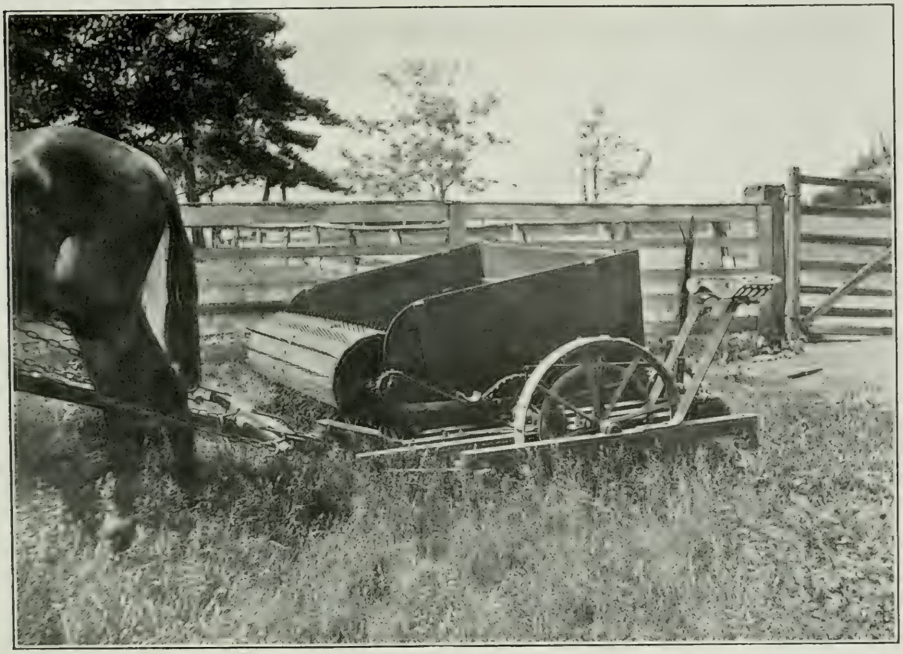

FIG. 1.—ROTARY CYLINDER STRIPPER.

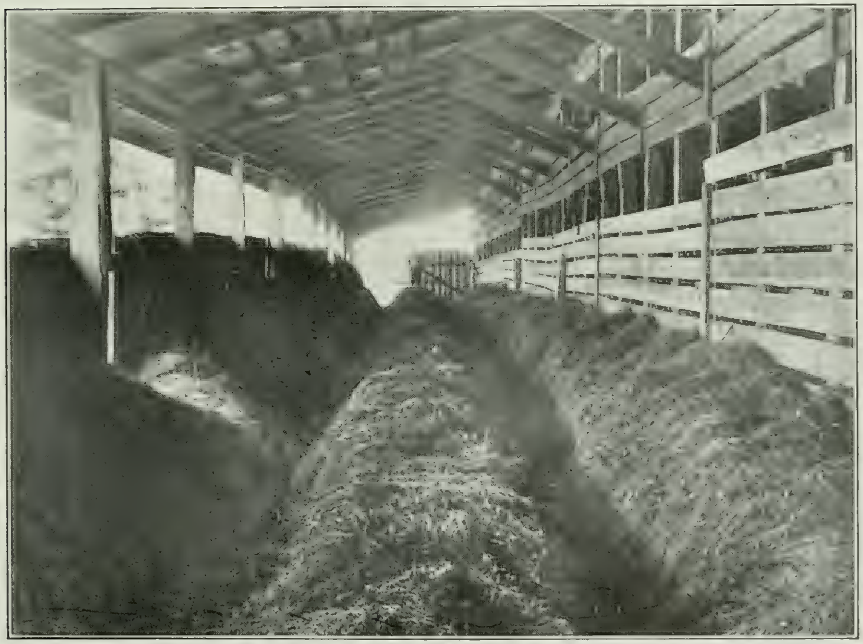

FIG. 2.—CURING BLUEGRASS SEED IN OPEN SHED.

large quantities of seed are to be cured, the ricks are made 4 or 5 feet high by about 5 feet broad at the bottom. In the fields the ricks are frequently as large and are from 50 to 200 or more feet long.

To cure in the field a space is first mowed close, and is sometimes scraped, leaving a smooth, hard-packed clay surface. The seed is then ricked up on the dirt or on the short grass stubble, much of the coarse stuff, such as weeds and timothy, being shaken out and removed at this time. Some cure their seed out of doors for the first three or four days, during which time, if the weather is favorable, the seed becomes nearly dry. It is then taken to barns to finish curing, when it can be piled in larger ricks than would be safe with fresh seed. The curing of the entire crop is usually completed at about the same time, as the greener seed collected first takes a much longer time than that which is allowed to fully mature before stripping.

Until the last few years the curing was all done by the persons who stripped their own seed, and consequently in small lots. Recently it has become more and more the custom to sell the rough seed as soon as it is stripped to dealers who either have cleaners of their own or who cure it in large quantities and then resell before it is cleaned. This system has necessitated the handling of very large bulks of seed in one place—often more than there is room for or than can be sufficiently stirred with the available help. This is especially true when it is cured in buildings.

TURNING THE RICKS.

After the seed has been piled up it is of the utmost importance that it should be stirred often to prevent heating. For this a force of workmen is kept busy turning the seed over with forks and shaking out the straw, so that the air may get to every part. Every rick should be turned at least three times daily for the first four or five days.

HEATING.

When the seed is taken from the stripper and put into sacks it is fresh, moist, and mixed with more or less green stuff. The closely packed mass heats and, if left for even a short time before emptying, the seed becomes decidedly warm to the touch. When this warm mass is then piled into ricks and left for several hours the temperature rises rapidly, and, unless the seed is frequently stirred, soon reaches a point at which the vitality is greatly damaged. Naturally the temperature rises most rapidly and reaches the highest points in the center of large ricks, and when for any reason these are not turned often enough, the seed becomes "funked" or fired and assumes a gray, dusty appearance with a musty smell, the vitality of the seed being damaged or entirely destroyed in proportion to the amount of heating allowed. When cleaned such seed is very dark-colored and always retains some of its mustiness.

RELATIVE MERITS OF INDOOR AND OUTDOOR CURING.

Whether indoor or outdoor curing is best depends mainly upon the weather at the time of curing, and, also, somewhat upon the floor space available for indoor work. The seed will unquestionably cure much quicker when put outdoors and exposed to the free circulation of air and the direct rays of the sun than when put in buildings in the shade. This is only the case, however, when the weather is clear, for whenever it rains the seed outdoors can not be stirred on account of the wet ground and the layer of wet seed on the outside, and in the meantime the center of the rick begins to ferment and heats very rapidly. The injury does not come from the rain itself, but from the heating, as seed is seldom if ever found wet more than one-half inch deep, even after a hard rain. When the curing takes place under cover the seed can be stirred constantly without reference to the weather, and although the process is slower it can be kept in good condition and free from injury by heating. The indoor curing is at all times safer if there is floor space enough, but it requires more labor and takes longer. Those curing indoors are, however, independent of the weather and can stir the seed whenever necessary. The greatest danger in connection with indoor curing is that, owing to restricted floor space, the ricks will be made so large (Pl. VI, fig. 1) as to develop a high temperature before they can be turned.

Both systems have as advocates equally successful and careful handlers, and under each good seed is made, the quality depending more on the conscientious care given by the curer than upon the method employed.

In fair weather seed may be cured outdoors in a week or ten days, while two or three weeks are required for indoor curing.

CLEANING.

The present development of the bluegrass-seed trade has been rendered possible by means of improved cleaning machinery. Before the civil war all bluegrass seed was cleaned by hand, negroes rubbing it through wire screens, their hands being protected by old boot legs. In the early years of the century lime and sand were used to assist in cleaning the seed; thus, Nicholson, in the Farmer's Assistant, published in 1814, says of *Poa pratensis:* "It yields plenty of seed, but this is difficult to sow on account of the filaments causing them to adhere to one another. To remedy this it is recommended to put them in newly slaked lime to separate them and then to be rubbed in dry sand."

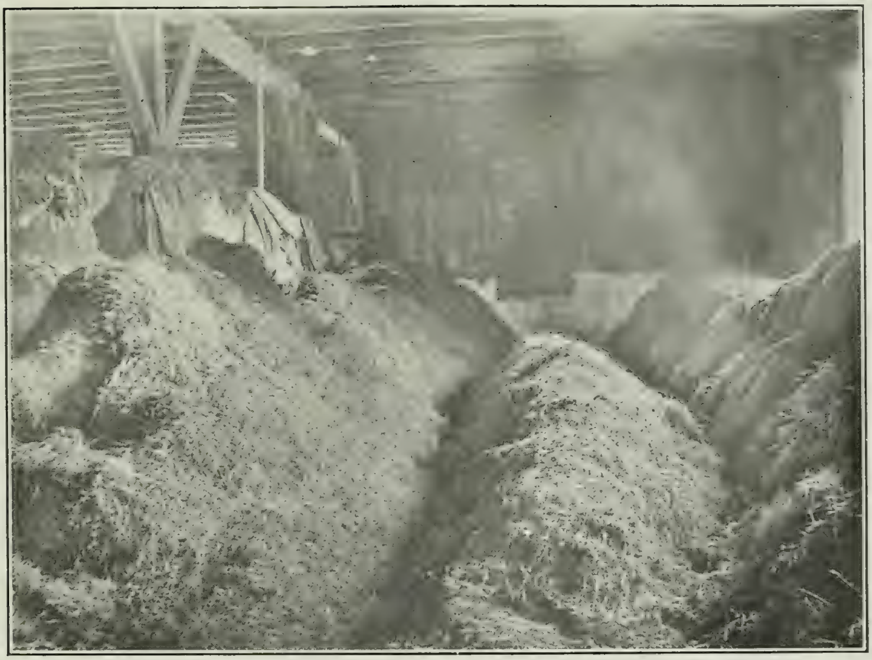

FIG. 1.—CURING BLUEGRASS SEED IN WAREHOUSE LOFT.

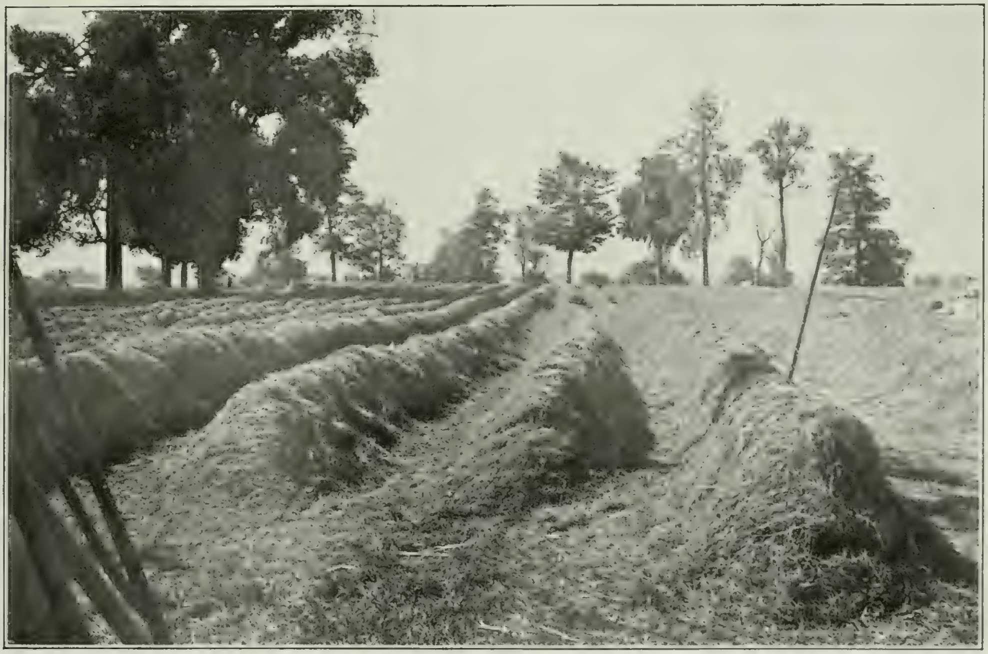

FIG. 2.—CURING BLUEGRASS SEED IN RICKS OUTDOORS—50,000 BUSHELS ON ONE CURING GROUND.

To-day the seed is cleaned with powerful machinery, so that hundreds of bushels of "fancy" can be turned out in a day. The rough seed is first run onto a cylinder which is armed with steel teeth and which revolves in a jacket of heavy wire mesh. The grass is rubbed between the mesh and the cylinder and the seed rubbed out. It is then sifted and run through a bran polisher, or some similar machine, to loosen the wool, after which it is finally cleaned through one of the modern seed-cleaning machines, which blows out the wool, dust, and light seed, leaving the "fancy" grade of any desired weight per bushel. The seed demanded by the export trade must weigh at least 22 pounds to the measured bushel.

EFFECT OF CURING ON THE VITALITY OF THE SEED.

During the past summer a careful study was made of the temperatures in the piles of curing bluegrass seed. A stay of about four weeks in the bluegrass region of Kentucky during the harvesting season, with daily visits to the principal curing grounds, made it possible to collect a series of samples taken under known conditions as to the time of harvesting, length of time the seed had lain in ricks without turning, and temperature of the seed when the sample was taken. These samples were dried as soon as drawn and sent to the seed laboratory, where they were cleaned by hand and the cleaned seed tested for germination. The conditions from the time the samples were drawn to the completion of the germination test were the same for all samples. The results of the germination tests are shown in the tables following.

About 70 samples of seed were collected, part of them being average samples taken from large lots of seed that were being cured under the ordinary conditions, but at different stages during the process, while others were taken to ascertain the actual time and temperature of fermentation. In order to do this a quantity of seed was repeatedly placed in a rick on the ground as soon as brought in from the strippers and not stirred for several days. Thermometer[a] bulbs were placed in the piles when the seed was put on the ground, and samples were taken at frequent intervals from these piles, the temperature of the mass being determined at the same time.

GERMINATION TESTS.

The following tables show the results of the germination tests of the samples mentioned above.

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[a] The temperatures of the piles of fermenting seed were taken with electrical thermometers of the pattern used in the Bureau of Soils and described in Bulletin No. 15, Division of Soils, U. S. Department of Agriculture. These instruments allowed the readings to be made as often as desired without removing the bulbs or in any way disturbing the temperature.

TABLE No. 1.—*Seed stripped June 20; put in rick on ground June 20, 6 p. m.*

Sample.	When taken.	Temperature, degrees F.	Part of rick.	Percentage of germination.
a	June 21, 10 a. m	140	Inside	0
b	June 21, 10 a. m		Top	79
c	June 21, 7 p. m	148	Inside	3
d	June 22, 5 p. m	130	do	0
e	June 24, 7 a. m	124	do	0.5

Table No. 1 shows the result of tests of samples taken from seed which was stripped on June 20 and put in a rick on the ground that afternoon about 6 o'clock. The next morning at 10 o'clock, after the seed had been in the rick for only sixteen hours, it had reached a temperature of over 140° F., and the sample taken at that time from the inside of the pile failed to germinate, while another sample taken at the same time from the outside of the rick gave a germination of 79 per cent. As the seed was practically killed at the end of the first sixteen hours, the samples taken later failed to germinate at all, or gave such a low percentage that they showed the seed to be of no value.

TABLE No. 2.—*Seed stripped June 19; put in rick on ground June 19, 5 p. m.*

Sample.	When taken.	Temperature, degrees F.	Part of rick.	Percentage of germination.
a	June 20, 10 a. m	130	Inside	75.5
b	June 20, 10 a. m		Top	92.5
c	June 20, 6 p. m	131	Inside	1
d	June 21, 10 a. m	140	do	.5
e	June 22, 5.30 a. m	145	do	0
f	June 22, 5.30 a. m		Top	77
g	June 22, 5 p. m	140	Inside	1

Table No. 2 shows the result with samples taken from seed stripped on June 19 and put in a rick on the ground that afternoon. The next morning, after about seventeen hours, the temperature was 130° F., and a sample taken from the inside of the rick germinated 75.5 per cent, while that taken from the top of the rick at the same time germinated 92.5 per cent. The temperature in this case did not run up as fast as in the case of the rick shown in Table No. 1, but the sample taken after twenty-five hours germinated only 1 per cent. After sixty hours the sample taken from the top of the rick germinated only 77 per cent, having fallen off about 15 per cent in two days from the effect of the heating, although on the outside of the rick.

TABLE NO. 3.—*Seed stripped June 18; put in rick on ground June 18, 6 p. m.*

Sample.	When taken.	Temperature, degrees F.	Part of rick.	Percentage of germination.
a	June 19, 2 p. m	148	Inside	3
b	June 19, 2 p. m		Top	91
c	June 20, 10 a. m	142	Inside	.5
d	June 20, 6 p. m	132	...do	.5
e	June 20, 6 p. m		Top	1.5
f	June 21, 10 a. m	104	Inside	.5
g	June 21, 10 a. m	[a] 153.3	...do	.5

[a] This temperature was that recorded by a maximum thermometer, which was placed inside the rick and not removed until it was opened at the time the last sample was taken.

Table No. 3 shows the germination of samples taken from seed stripped on June 18 and put in a rick on the ground that afternoon at 6 o'clock. The next afternoon, after twenty hours, the temperature was 148° F., and the sample taken then germinated only 3 per cent, while that taken from the top of the rick at the same time germinated 91 per cent.

TABLE NO. 4.—*Seed stripped June 18; put in sack on ground June 18, 10 a. m.*

Sample.	When taken.	Temperature, degrees F.	Part of sack.	Percentage of germination.
a	June 20, 10 a. m		Top	55
b	June 20, 6 p. m	134	Inside	39.5
c	June 21, 10 a. m	128	...do	41
d	June 22, 5 p. m	135	...do	9
e	June 24, 7 a. m	130	...do	1

Table No. 4 shows the germination of samples taken from a single 10-bushel sack of seed stripped on June 18 and laid on the ground outdoors. As there was a smaller bulk than in the ricks the temperature did not run so high, but the vitality of the seed was steadily reduced and at the end of four days was practically destroyed.

TABLE NO. 5.—*Average samples from bulk lots.*

Sample No.	When stripped.	When sampled.	Where cured.	Percentage of germination.
6	June 22	June 25	In barn (not stirred)	0
8	June 28	June 28	In warehouse	75.5
10	June 20	June 25	do	35
11	do	do	do	42
12	do	do	do	20
14	do	June 26	do	84
15	do	June 24	In barn	17
16	June 22	do	do	87
18	June 20	June 21	On grass	69
19	June 21	June 27	do	43
20	do	do	do	92
22	June 14	June 20	In barn	2
23	June 17	June 21	On ground	87
24	June 19	do	In house	78
26a	June 18	June 18	In barn	52
26b	do	do	do	77
27	June 19	June 27	do	81
28	do	do	In open shed	81
29	June 22	do	In barn	66
30	do	June 26	In warehouse	25
31	June 14	do	On ground	3

Table No. 5 shows the germination of 21 average samples taken from large lots of seed which were being cured in the ordinary way. Of these, 6 germinate 25 per cent or less and are worthless as commercial samples, while 9 germinate over 75 per cent and would be graded as first-class seed. The other 6 samples, germinating from 35 per cent to 69 per cent, would be considered poor to fair.

SUMMARY OF RESULTS.

These tests show that only half, or less than half, of the seed is cured in a way which makes it first quality and sufficiently good to be sold in the European market, where a large part of the best seed is sent. Radical changes should be made in the methods of curing. It is absolutely necessary that the seed should not be left twelve to sixteen hours without stirring, as the heating from fermentation will destroy the vitality of the seed in that time. When the curing takes place outdoors, with the possibility of not being able to stir the seed during a rain, the ricks should not be over 16 to 18 inches high nor more than 12 inches wide at the bottom. If they are made as small as this, the air will have a chance to circulate through them and prevent excessive heating.

The tests also show that this seed naturally has good vitality and that there is no reason why Kentucky bluegrass seed should not rank as high in respect to quality as clover or timothy seed.

ARTIFICIAL CURING.

An attempt was made to try the practicability of curing the rough seed by means of a commercial grain dryer, or a modification of it. A quantity of seed was sent to Chicago and dried very quickly and economically, but it had heated in transit, so that the samples taken when it reached Chicago failed to germinate. There would be no possibility of injury to the vitality of the seed if the drying was done at a low temperature and with a large blast of air. If the seed was only partly dried in some such manner it could then be handled with very little danger of heating, as the most severe fermentation takes place immediately after stripping, while all the water is in the seed and straw. A plant to thoroughly test this method of curing should be established the coming season, as its successful operation and adoption would mean a great saving in labor, as well as a great improvement in the quality of Kentucky bluegrass seed.

CONCLUSIONS.

1. Green seed of Kentucky bluegrass when put in ricks will ferment and reach a temperature of 130° to 140° F. in less than sixteen hours.
2. A temperature of 130° to 140° F. for sixteen hours or less will greatly damage if not entirely destroy the vitality of the seed.
3. Under the present methods of handling green seed it must be stirred at short intervals.
4. The seed must not be stripped till mature, as it is much harder to prevent fermentation in the immature seed.
5. Seed should always be put in small ricks, not over 18 inches high.
6. Seed can be cured to better advantage under cover in bad weather and outdoors in clear weather.
7. A plant for thoroughly testing artificial curing should be established at once.

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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN No. 20.
B. T. GALLOWAY, Chief of Bureau.

MANUFACTURE

OF

SEMOLINA AND MACARONI.

BY

ROBERT P. SKINNER,
Consul General at Marseille.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 8, 1902.

Sir: I have the honor to transmit herewith a paper on the manufacture of semolina and macaroni, and respectfully recommend that it be published as Bulletin No. 20 of the Bureau series. The report was prepared by Hon. Robert P. Skinner, Consul General at Marseille, France, and was submitted by the Pathologist and Physiologist.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

For several years past investigations of macaroni wheats have been carried on under the auspices of this Office for the purpose of promoting the wheat industry in this country, the work being in charge of the cerealist, Mr. Mark Alfred Carleton. A large amount of seed of the best quality has been imported from Russia, Algeria, and Argentina, and many of the varieties have been found to be admirably adapted for cultivation in our Great Plains region. Farmers have become much interested in the subject and the acreage planted to macaroni wheats is increasing each year with remarkable rapidity. As the use of the true durum wheats for macaroni is entirely new in this country, there is a great desire on the part of millers and macaroni manufacturers to understand more concerning the process of grinding these wheats into semolina and of making from this the various forms of macaroni.

The largest semolina factories are in France and Italy, where the greatest amount of good macaroni is produced. We are indebted to our consuls, Mr. Robert P. Skinner, Marseille, France, author of this report, and Mr. John C. Covert, Lyon, France, for much valuable information on the subject, and considerable of this has been published in Bulletin No. 3 of the Bureau—Macaroni Wheats.

The present report is of interest to the farmers in regions where the macaroni wheats can be grown, and of special interest to the millers and manufacturers in this country, and Mr. Skinner suggests that more attention be given to the export of semolina, as well as macaroni wheat.

Albert F. Woods,
Pathologist and Physiologist.

Office of the Pathologist and Physiologist,
Washington, D. C., February 7, 1902.

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B. P. I.—25. V. P. P. I.—96.

MANUFACTURE OF SEMOLINA AND MACARONI.

INTRODUCTION.

A NEGLECTED OPPORTUNITY.

The Secretary of Agriculture has observed that an increase of 1 bushel per acre in the average yield of American wheat would add enormously to the wealth of our country. He might have added, with equal truth, that the advantage of this increased production would be minimized unless remunerative markets could be found for the increasing surplus, and as it is the peculiar field of the Department of Agriculture to increase crops, so it is the especial duty of the consular service to seek for new markets. There is a market in Marseille that has grown from nothing within the last thirty years and is increasing by leaps and bounds, not only in this city, but throughout all Europe, its present daily requirements being 24,000 bushels of wheat. The ebb and flow of this market within recent years has been controlled by crops and not by the consuming public. The cry of this trade is for raw material, and, according to the last available expression of the Marseille Chamber of Commerce, the manufacturers of this city, deprived of a sufficient quantity of hard wheats from Russia, have been obliged to employ the "metadiné" wheats of interior France, which, owing to their inferiority, "have affected the quality of the edible pastes, the consumption of which has therefore been diminished." The raw material for this industry consists of hard or durum wheat, which is ground into semolina and then manufactured into macaroni, the latter word being here used as a generic term. The business has developed in the colonies of Algeria and Tunis a great wheat-growing industry. After satisfying domestic demands, the manufacturers of Marseille have exported a surplus amounting, in 1900, to 81,403,266 pounds of semolina and 10,811,356 pounds of manufactured macaroni.

Although one of the greatest wheat-growing nations of the world, France is prevented, because of its soil and climate, from producing the grain essential to the life of this industry; and the United States, the greatest of all wheat-growing countries, has yet to send its first pound to this port for the purpose above described. My present object is, therefore, to urge upon our wheat-growing farmers the further specialization of their business, first, as a means of engaging in this Mediterranean trade, and, second, in order that we may build up in the United States a demand for the food products which we can have in all their excellence only after we have produced a sufficient supply of the durum wheat needed.

To the lay reader I may say that the so-called "hard wheat" of the United States is not at all the hard wheat of Europe, and the semolina now being manufactured in a small way in the United States from our native wheats, while a worthy product, is not acceptable in this market as a competitor with the semolina of first quality of local manufacture. Yet there is great encouragement to further effort and closer study on the part of our manufacturers in the success already attained: for, if the American product of the present is unavailable in France, the doors already swing inward for it elsewhere. In proof of this I have been shown by a Marseille exporter a letter written from Russia, in which it is stated that the Russian manufacturers "can not to-day pay the price demanded [for semolina] in Marseille, because the American granulated flours are offered cheaper; that is to say, $4.25 per 100 kilos (220 pounds), or 50 cents less than French quotations."

It is insufficient, however, to have made merely a good beginning. Every student of the situation, every importer of wheat, recognizes that we are lacking in the prime essential to complete success, that is, a wheat ranking with the macaroni wheats of Sicily, Russia, and Algeria.

DEVELOPMENT OF THE INDUSTRY IN FRANCE.

If the average person should be asked whence macaroni comes, he would answer immediately "from Italy." At one time this was true, and it arose from the fact that the native wheat of Sicily and that southern portion of Italy known as La Pouille possessed all the attributes deemed desirable in the typical macaroni grain. The industry had its birth in Naples, and the reputation of the Neapolitan manufacturers rests to-day mainly upon the fact that they had this wheat with which to work. In the course of years the Italians have neglected the cultivation of the grain, many wheat fields having been planted over with vines, so that now, commercially speaking, the hard wheat of Sicily and La Pouille is unimportant; nevertheless, its quality is as highly appreciated to-day as ever, and modern farming in Algeria owes much to the lessons learned from Sicily. With the growth in their business and the decrease in their supply of home-grown grain, the Italian manufacturers looked elsewhere for their supply of raw material, and they turned naturally to Marseille, a city where capital and business enterprise abounded. The Marseillais, always great manufacturers and exporters of flour, rapidly grasped the situation, began to import durum wheat from Russia and Algeria, ground it into coarse flour—which we call "granulated flour" or "semolina," or in French "semoule"—and sold it to the Italians. The exports of this product from Marseille to Italy last year amounted to 3,510,111 pounds.

It was but a step from this starting point to the manufacture of the macaroni itself; and one improvement following another, and, the public demand for macaroni and other edible pastes rapidly increasing, they established large factories alongside their mills, and exportation began to all parts of the world, even to Italy itself. With the introduction of the Budapest roller process of grinding flour, the business expanded upon modern lines; and, whereas years ago every Italian family made its own macaroni and hung it out on the racks to dry, the manufacture has now become an industry of first-rate importance, requiring capital and enterprise.

As this is an elementary discussion of the matter, I venture to observe that our own homely dish of "noodles" could be traced back to the Italian macaroni. The difference between the two is that the macaroni is manufactured from coarse hard-wheat flour, or semolina, in making which the manufacturer attempts to remove the outer husk and break up the grains so as to secure granules rounded and glazed, instead of the impalpable powder of which ordinary flour consists. Macaroni (which I shall frequently use as a generic term covering all the manufactured products of semolina) is, strictly speaking, applicable only to the long, hollow tubes of dry food paste. This paste consists merely of semolina and water kneaded together; and it is converted into hundreds of forms, sometimes inelegantly referred to in English as "edible pastes," or in French as "pâtes alimentaires."

FRENCH METADINÉ WHEATS.

Until something like ten years ago, when the present French tariff upon wheat was imposed, all of the French macaroni was manufactured from semolina made from hard durum wheat. At that time considerable quantities of mixed wheat, or metadiné, were grown in France, but were manufactured into common flour, and were highly regarded. During the last ten years a steady increase has been noted in the amount of this wheat grown in France from durum seed, and more and more of it has been used for the manufacture of macaroni pastes. It is recognized that the semolina manufactured from these wheats is inferior to the standard Marseille type of semolina, but the difference in price on account of the tariff makes it advantageous to use the domestic wheat. The extension of the manufacturing business has slowly progressed from the city of Marseille to a very considerable portion of France, in which these mixed wheats are grown. The Marseille manufacturers have been slow to recognize that the growth of this branch of the semolina business has been such as to constitute it a very respectable competitive force. The macaroni manufacturer never uses the metadiné semolina without an admixture of more or less durum wheat semolina, and the product, which is much cheaper in the market, is consumed almost entirely in France. The product of this mixed semolina is never macaroni, properly speaking, which can only be manufactured successfully from a strictly hard wheat, but the metadiné semolina makes a satisfactory macaroni paste, sold in the form of vermicelli, escargots, stars, and other arbitrary shapes used for soups and various dishes very popular in France.

The metadiné wheat of France, peculiar to the Department of Gard and that of Vaucluse, is a half-hard wheat, resulting from the sowing of a genuine durum which deteriorates. The wheat produced can not be planted for a second crop. The durum requires less care than soft wheat in the regions where it is grown, and the yield is larger. This wheat also resists climatic changes much more readily than the native French wheat, and can better stand a dry season.

GROWTH OF THE DEMAND FOR MACARONI.

More interesting than the development of the manufacture of semolina is the history of the increase in the consumption of the edible product.

The broad lines of this development have been thus described by Mr. François Scaramelli, one of the most important manufacturers of edible pastes in the world, and an exporter of large quantities to the United States (Plate I, fig. 1). Mr. Scaramelli says:

> The manufacture of macaroni pastes has doubled in Marseille within ten years, and the domestic consumption of the product has also increased and continues to increase enormously. In 1866, when I first traveled about the country selling the output of our then small factory, I once reached the village of the Grande Combe, where I found that the only dealer in macaroni was the local druggist, who said that he bought 25 pounds per annum, which was sold exclusively for consumption by invalids. At the present time, the same village takes 25,000 pounds of macaroni per month, which is sold practically to every family in the place. It has become a staple article of diet, replacing to a large extent the peasant soups, formerly made of bread and vegetables. In the city of Marseille, the consumption has tripled in twenty-five years. In 1872 there were ten macaroni factories in Marseille, producing 220 pounds per day each. There are now 55 local factories, turning out a total of about 85,000 pounds per day. The industry requires the labor of from 400 to 500 men, and from 500 to 600 women, according to the season. With two or three exceptions, these macaroni factories are very small affairs, catering to a local demand, but the aggregate of their business is large. I naturally look for the gradual extinguishment of these smaller concerns, and the absorption of their businesses by the larger. When the consumption of edible pastes began to move forward with giant strides the manufacture of the article seemed to promise large returns to persons of limited means, but the improvements in the mechanical processes and the necessity for heavy investment in order to keep abreast of the times is bound to force weak competition from the field. I am speaking of the manufacture of macaroni exclusively. There are 127 mills for grinding grain in Marseille, of which 50 make more or less semolina,

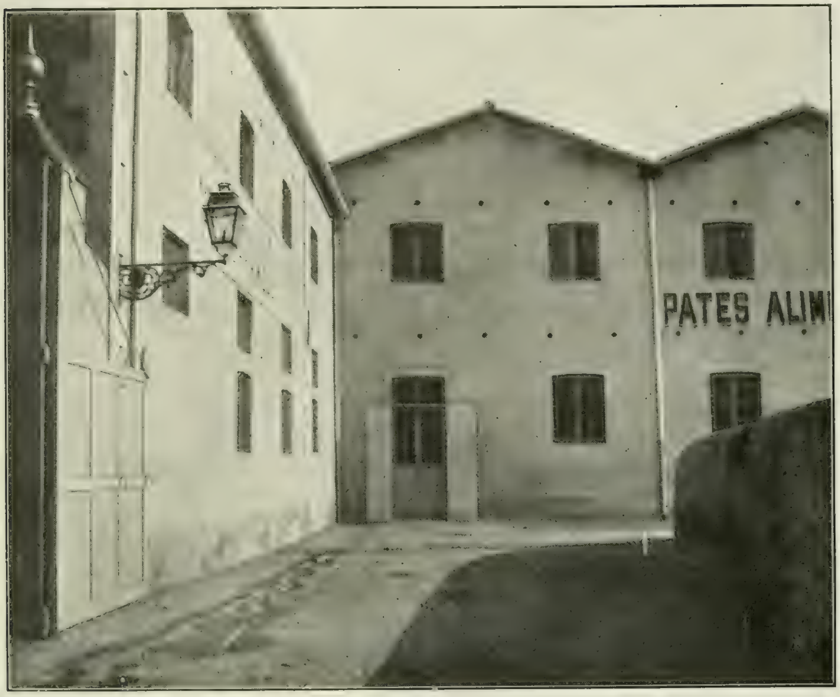

FIG. 1.—MACARONI FACTORY OF F. SCARAMELLI FILS AT MARSEILLE.

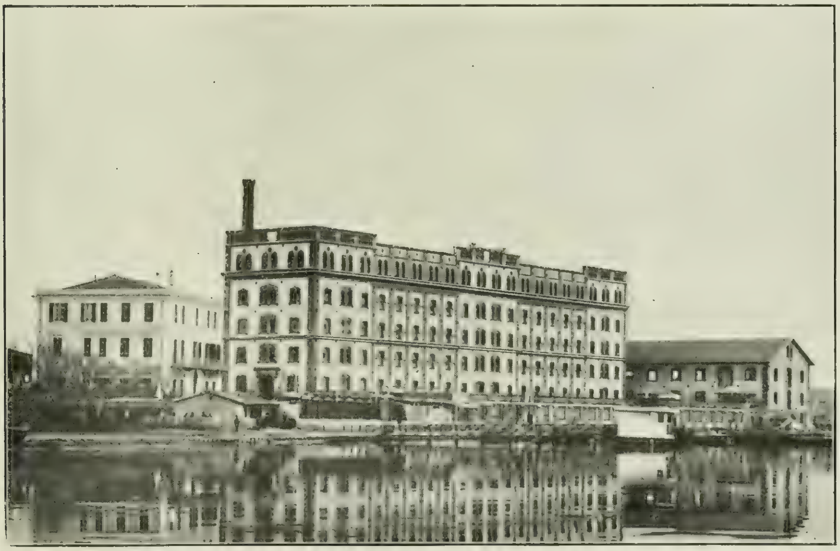

FIG. 2.—FLOUR AND SEMOLINA MILL OF ALLATINI & CO. AT SALONICA.

and 20 are devoted exclusively to this trade. It will thus be seen that the industry is a very important one from every point of view.

The extension of this business in Marseille is in less degree observable throughout the Mediterranean country. Semolina mills have been erected or are in course of construction in all the important wheat markets, and in the Levant, where the manufacture of this article dates from very recent years, the increase is especially noteworthy. Perhaps the largest semolina mill in the world (Plate I. fig. 2) is that owned by the great Italian firm of Allatini & Co., recently completed at Salonica, and having a consumption of 2,000 quintals (1 quintal = 220.46 pounds) daily of hard wheat. The reason for this rapid extension of the business is that macaroni in its numerous forms is a palatable, nutritious article which satisfies the desire for food at a very moderate cost, largely replacing meat dishes, which are steadily becoming more expensive throughout the world. There is no pretense that macaroni is a "health food" or a "breakfast dish," or that it contains a high percentage of nutrients or heat units. It is simply a food which appeases hunger and satisfies a healthy appetite. The excellence of this food is not generally known throughout the United States. The value of the declared exports of macaroni from Marseille to the United States for the fiscal year ended June 30, 1901, was only $44,504; and, while this was but a fraction of the total amount imported, it is reasonable to suppose that the grand total was not large.[a]

With the exception of a few especially well-served markets, the average macaroni sold in the United States has passed its prime before it reaches the consumer. Most of us have seen a few brittle lengths of stale vermicelli or still staler macaroni exposed for sale in glass jars, like old-fashioned stick candy, in the country grocery store. Few of our housewives have studied the possibilities of fresh macaroni as an article of diet. In Europe, on the other hand, it is sold when in its best state, and after passing through the hands of a competent cook can hold its own in a hundred different forms with any competing product which may be served, from soup to dessert.

NEED OF GROWING THE DURUM WHEAT.

The recipe for making a good dish of macaroni is like the famous rule for making a rabbit pie, "First catch your rabbit;" and the surprising fact in this connection is that, at this time, the United States has yet to grow the quality of wheat essential to the macaroni industry.[b] Before I saw the immense importance of the macaroni trade as a means of augmenting our exports of wheat, and being confident that in grain we could supply anything that the world might demand, I sent reports on the subject to the Department of State, written in 1899, advising exporters of the need of this market for a good hard wheat. To my astonishment it was promptly developed that we had no wheat of the quality required, and that the so-called hard wheat of the United States contained grains differing in degree of hardness, which speedily clogged the milling machinery, and was entirely unfitted for the purpose. The Department of Agriculture has since sent experts to Europe to study the question. I have no doubt that their researches will add much more to the stock of useful information than my present effort to describe the business as seen by a layman, and as it is conducted to-day.

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[a] The total import for the year ending June 30, 1901 was 18,186,399.83 pounds, valued at $735,239.49—M. A. Carleton.

[b] About one million bushels of the durum wheat will probably be produced in 1902—M. A. C.

THE MARKET FOR DURUM WHEAT.

WILD GOOSE WHEAT.

Before proceeding to a more technical account of this matter, it may be useful to report the results of a number of interviews with Mr. G. P. Bottazzo. Mr. Bottazzo has created a very large business for himself in this city as a broker of semolina, and his views of the possibility of serious American competition are entitled to high respect. It is fair to mention that his opinion of the Canadian Goose wheat which he describes is not shared by all of the experts in this city.[a] Mr. Edmond Bendit, a very extensive importer of grain, to whom a a sample of the wheat in question was submitted, declared that, while appearing to be of excellent quality, and of a hardness sufficient for the semolina trade, it could not be claimed for it that it equaled the best Russian wheat. Substantially the same opinion was given to me by the firm of Allatini & Co. These are manufacturers of semolina at Salonica, and one of the most important houses in Marseille. Both Mr. Allatini and Mr. Fernandez of the same firm commended the appearance of the wheat and of the semolina it produced, but seemed to think that it was deficient in gluten, and could not be relied upon to produce a satisfactory macaroni without the admixture of a stronger product. Mr. Bottazzo's less measured statement is as follows:

> Since the 1st of May, 1901, we have received at Marseille about 100,000 tons of hard Goose wheat, shipped by New York firms, and supposed to have been grown in Manitoba. I am satisfied that it has been grown from Russian seed, and it is perhaps three or four crops removed from the original seed. In past years, other Goose wheat has been offered for sale, but the quality until this year has never been such as to enable us to use it for the manufacture of semolina. This Goose wheat of which I speak is as good as any macaroni wheat ever sold in this market. It is all being consumed in the semolina mills at Marseille, to the entire satisfaction of the pur-

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[a] It should be observed that Canadian Goose wheat is already known to be inferior to that grown in North and South Dakota.—M. A. C.

chasers. It sells at from 3 to 5 cents less than superior Taganrog, and it ought to command as high a price, but being less well known it has that disadvantage to overcome. It contains from 12 to 14 per cent of dry gluten.

PROSPECTIVE DEMAND FOR AMERICAN HARD WHEAT AND SEMOLINA.

Continuing in response to queries, Mr. Bottazzo said:

I am not interested in the development of American commerce, but I consider that the laws of trade are higher than those of governments; that business should be developed under circumstances most favorably adapted for such development, and that the transfer of an industry from one point to another is generally compensated for by some advantage accruing to the locality thus temporarily affected. It is for this reason that I believe America to be capable not only of supplying the hard wheat requisite for the macaroni trade, but the semolina as well. I call your special attention to the fact that, up to this time, you have only concerned yourself with the production of a hard wheat for our market. I ask that you go a step further, and convert that wheat into semolina. You tell me that semolina is a perishable product, but I answer you out of my experience that this is largely a matter of assumption. If semolina is thoroughly well made in the first instance, there is no question that it will stand transportation, and retain all of its good qualities for any reasonable length of time. I have personally known semolina properly manufactured that was found to be in a perfect state after eighteen months. Our difficulty in Marseille is this: We receive wheats from all parts of the world, varying in degree of hardness, differing in the size of the kernels, and in their component parts. The mills themselves are comparatively small. Considerable quantities of semolina are manufactured to order for commission houses. Thus the manufacturer is obliged to change his process to suit rapidly varying conditions, and is never enabled to keep his machinery geared to any average standard of wheat, and for that matter never acquires an absolute knowledge of any one wheat, such as your millers in the United States are able to acquire. You will have no difficulty, if you pay proper attention to the matter, in growing macaroni wheat in the United States in unlimited quantities, and, having done that, your manufacturers will have no excuse for not operating their mills year in and year out with the same kind of wheat, thus permitting them to study and correct every defect and place upon the market a semolina equal to the best of which we now know.

It is believed that a market could be built up in Europe for from 10,000 to 15,000 bushels of semolina a day. Let your manufacturers describe to me their system, tell me whether they wash or do not wash their wheat, the time they devote to the scouring process, the exact interval of time between the scouring process and the beginning of the grinding; let them describe their means of purification of the semolina after grinding, and if they will send to me every detail, I will return to them all the supplementary information they require to achieve a satisfactory result. Let them send samples of their actual production. The semolina now manufactured in the United States and of which I have seen samples, although produced from comparatively soft wheat, is yet a marketable product. I am satisfied that firms now in this business in a tentative way could very readily equip themselves for the production of a superior grade of semolina. The first thing for us to have in Marseille is samples.

EUROPEAN METHODS AND PRODUCTS.

Speaking of the European macaroni wheats and semolina, and the methods employed in the manufacture of the latter, Mr. Bottazzo said:

When different qualities of wheat are mixed before the grinding process begins, the product is inferior. The miller has need of but one particular quality of wheat to produce semolina. After the semolina is manufactured, a mixture is sometimes effected, in order to secure a certain standard. No hard wheat has less gluten than the wheat of Salonica, and the wheat of Salonica has always stood at the head, because it is always handsome when purified. One of the principal manufacturers of edible pastes in Marseille purchases semolina from each of the fifteen millers and the semolina of the same size is mixed together indifferently for the manufacture of the product. Of course, when a particularly fine macaroni is required for a special purpose, there is a special effort made to procure semolina corresponding to the high grade of macaroni required. The great point concerning semolina is its purity.

The territory northwest and northeast of the Azov furnishes the hard wheat most appreciated at present, and containing the greatest quantity of gluten. After Russia, and in order of importance as countries growing hard grain, come Algeria and Tunis, India, and Chile. The Chilean wheat has a rubbery quality, and is neither regular nor hard.

It is possible to arrange a mill for the manufacture of either semolina or flour by the change of cylinders, but the product is necessarily inferior. To produce semolina of the first quality the mill should be constructed exclusively for that purpose. Here it is necessary to wash the wheat, for the simple reason that it is very dirty, and contains much earth and other impurities. But in America a thorough dry cleaning would suffice, and it will be necessary to follow this plan in order that the product may be preserved. It is perfectly possible to dry-clean the wheat, and brush it, by employing what we call "désagrégeurs." After passing through this machine, if the process is well carried out, the wheat is absolutely pure, and the semolina resulting from the manufacture of wheat thus cleaned may be preserved for a long time. The semolina manufactured at Marseilles is never dried after manufacture, for the great reason that it is consumed in this market promptly, and the process is unnecessary. The production of semolina involves the production also of a certain percentage of an inferior flour.

Semolina has been manufactured here for sixty or eighty years. The business has been materially extended within the last twenty-five years. Marseille is the center of the industry. The extension dates more particularly from the introduction of the purifiers in mills. At present the industry is extending rapidly throughout Italy; in France, in the cities of Valence, Lyon, Montelimar, and Toulouse; in Germany at Mannheim and Königsberg; in Russia, in Greece, and in Tunis and Algiers. We receive at Marseille annually 100,000 barrels of two hundredweight of semolina from Constantine, Algeria. At Salonica 1,000 sacks are made per day, and sold very generally. At Smyrna also there are mills, which, however, are very bad, and the semolina is used for the manufacture of "pates alimentaires," although a certain quantity is also used in the manufacture of various kinds of bread.

SCOURING THE GRAIN.

Before leaving Mr. Bottazzo's statement, it should be added that his contention in favor of eliminating the washing process in American semolina mills opens a field of controversy which only actual experience can settle. While Mr. Bottazzo assumes the washing process to be necessary in Marseille because of the foreign matter generally found in Old World wheat, and while I have found other practical men who charge that the scouring process is to some extent adopted in order to give the product additional weight, I have equally strong expert opinion to the effect that the moistening of the grain enables the removal of the bran in less broken particles, while dry grinding causes it to crack and enter into the semolina itself, from which it can not be entirely removed. Mr. Bottazzo's statement was shown to Mr. Jean Baptiste Lautier, a practical miller, who said:

> Mr. Bottazzo is not entirely correct in his assumption that satisfactory results can be obtained in the manufacture of semolina without the scouring of the grain. Our experience in Marseille is that the moistening of the grain causes the bran to flake off in large particles during the milling process, enabling us to secure not only a first-class quality of semolina, but also a merchantable quality of flour. When the wheat is dry-cleaned the bran, being more brittle, enters into the various products the more readily, and while the semolina thus produced is of good quality, the flour is of inferior quality and very unattractive in appearance. The proportion of fine semolina obtained by the dry-milling process is about the same; but the relative proportion of large semolina, which is the most desired, is from 3 per cent to 4 per cent less. The practice of scouring the wheat is subject to no exceptions in Marseille, and the matter of moistening it is so important, especially in its effect upon the appearance of the semolina, that if the scouring process is insufficient in any respect the manufacturer is sure to bring reproach upon himself. Absolutely the only dry-milling undertaken in Marseille is for the account of Jewish clients, who require the flour for the production of their unleavened bread once a year. If the only question confronting the manufacturer was to preserve his product for a considerable length of time, doubtless an attempt to avoid the washing of the grain would be advisable.
>
> I might suggest one method of securing the advantages of both wet and dry cleaning sometimes followed in this city. If instead of permitting the wheat to repose for from 10 to 40 hours, as is usually the case, after passing through the water, it should be carried immediately to the machinery, the outer husk only being dampened would be removable in large flakes, and the speed with which the operation would be carried out would at the same time prevent the humidity from penetrating the kernel. I should be inclined to recommend this system in the United States, where the preservation of the semolina for a number of months would be important. In this manner the bran would be prevented from entering into the flour and semolina, and, while the flour itself might be perhaps a little less attractive in appearance, the net difference to the miller would be small.

MANUFACTURE OF SEMOLINA.

USING WHEAT FROM DIFFERENT COUNTRIES.

The statistics relating to the importation of wheat at Marseille appear elsewhere. There are 20 mills requiring from 7,000 to 8,000 quintals (1 quintal = 220.46 pounds) of raw material per day. There are also 10 mills which grind alternately the hard wheat for the macaroni trade and soft wheat flour for general purposes, according to the market. Mills of this class require about 3,000 quintals per day. There are 60 mills in this city grinding soft wheat into flour to the extent of from 12,000 to 15,000 quintals per day. The most important flour mill in this city requires 800 quintals per day of wheat, and the average requirement is from 200 to 300. In addition to the mills mentioned there are 5 other mills which grind beans into flour, requiring an aggregate of 1,000 quintals per day.

The durum wheats of Algeria, although containing less gluten than the semolina wheats of Russia, constitute a standard type for the manufacture of semolina, as the product is shiny and clear. As these hard wheats are very often insufficient in quantity for local purposes, and furthermore lack the necessary proportion of gluten, the resultant product of the wheat is very frequently mixed by the millers according to their special interests and the market prices. Ordinarily Algerian or Tunisian wheat is mixed with Russian or Turkish wheat, and sometimes with Indian. One authority was asked to supply formulæ for the composition of a theoretically perfect semolina, but he replied that, while millers and others might be disposed to discuss chemical composition in pedantic fashion, in practice there was very little attempt to realize elaborately spun theories, Millers and macaroni manufacturers by long experience were familiar with the appearance of semolina that would yield a certain quality of macaroni, and when they went into the market they smoothed down a sample on a sheet of paper, held it up to the light, looked horizontally across it, and if it was bright and clear, they bought. Wheats are always ground separately. Sometimes the manufacturer mixes the semolina himself, and sometimes the manufacturer of the macaroni does this.

CLEANING THE WHEAT.

The manufacture of the semolina begins with the cleaning of the wheat, including washing by water. The Russian wheats contain more moisture than the Algerian, and should be dampened more lightly, and allowed to repose during a shorter period between the scouring and the beginning of the grinding. The length of the repose after the scouring is a very delicate question for the Marseille miller to determine, as the moisture must penetrate to the heart of the grain in order that the bran and the cells of the wheat may be less broken up into flour, which of course the semolina manufacturer wishes to avoid. In the old days of grinding with millstones the wheat was not allowed to rest between the scouring and the grinding, but it was found by this means that the outer husk absorbed all the moisture and the by-products of the manufacture of semolina could not be secured. Since the application of the roller process in 1881 a uniform system of procedure has been followed in all of the French semolina mills, and distinct progress has been made in the intrinsic value of the product and in the amount of semolina per quintal of grain. This washing process is so important that I give a description of a typical French scouring system written by M. Charles Dantin.

In the manufacture of semolina in France, the wheat is first scoured with water, then dried, and then a second time moistened. It reposes, as previously explained, after the second application of moisture, for ten to forty hours before going to the cylinders. The first scouring

I venture to describe in some detail, using for the purpose the words of Mr. Dantin:

> An excess of humidity in the wheat exercises a dangerous effect upon the flour, involving the alteration of the gluten, development of organisms, disagreeable odor, and gray color. The maximum proportion of water should be 18 per cent, as milling becomes very difficult after the proportion reaches 20 per cent, the cylinders becoming clogged. As hard wheats are uniformly drier by nature, the washing process is easier than in the case of soft wheat. The washing operation leaves from 1 to 5 per cent of water incorporated in the wheat, the cause of this variation depending mainly upon the quality of the wheat. It is desirable of course that the grain conserve a certain degree of humidity, which benefits more or less a subsequent dampening, and facilitates decortication.

The advantages of the application of moisture, either in connection with the scouring process about to be described or as a succeeding operation, are thus set forth by Messrs. Millon & Mourin, of Algiers:

> The water, spreading readily upon the surface of the kernels, does not immediately penetrate into the interior. Wherever the surface is dampened, the adherence of the external pellicle is destroyed; the external tegument of the grain separated by decortication then forms bran of a remarkable lightness. Above all, the milling of decorticated wheat proceeds with regularity unknown in the case of the dry-cleaned wheat.

Water is therefore considered not only the most useful agent for cleaning wheat, even of such impurities as may lodge in the crevices of the kernels, but as one which facilitates the decortication itself. These are the considerations which have brought about the general adoption of some scouring device in France. The description below covers the essential points of the Savit & Boutet system for the purifying operation:

In the basin of the device the water is taken at a temperature varying with the season. Now, when upon still water one drops with care a grain of wheat with dry fingers, the grain floats a long time. If a pebble of the same size as the grain of wheat is dropped similarly, it may float also, but for a very short time, since the wheat has a density but little higher than that of water, and the pebble a density much higher. Upon this principle the Savit & Boutet machine is constructed. If, in place of depositing a grain with the fingers, it is dropped upon a curved surface with which the surface of the water forms a tangent, the wheat will still float. As to the pebbles, as they float but a short time, if the whole be permitted to continue in movement, the wheat will float to the end, while the pebbles will sink quickly. Thus we may extract bodies of greater density than wheat without immersing the latter. The apparatus (fig. 1) is composed of a flat receptacle *P*, which turns upon an axis forming a basin covered with water regulated from *O*. This basin possesses a flange around the edge, tending to prevent foreign bodies very slightly more dense than wheat from being swept along with it. The tube *T* receives the grain, which may be cut off by shutter at *V*. This tube feeds the wheat upon cone *E*, the inclination of which is such that the grain may fall upon the water with nicely adjusted speed, the grain being distributed upon the cone by the distributor (babillard) *B*, which is fixed on the vertical tree *A*. The basin *P* turns within and above a circular canal *C*, composed of two portions, one receiving the wheat and completely surrounding the basin; the other, *C″*, embracing the arc between the two jets of water *d′* and *d″* and receiving the particles of sand, etc. A cast-iron frame, *G*, supports the whole.

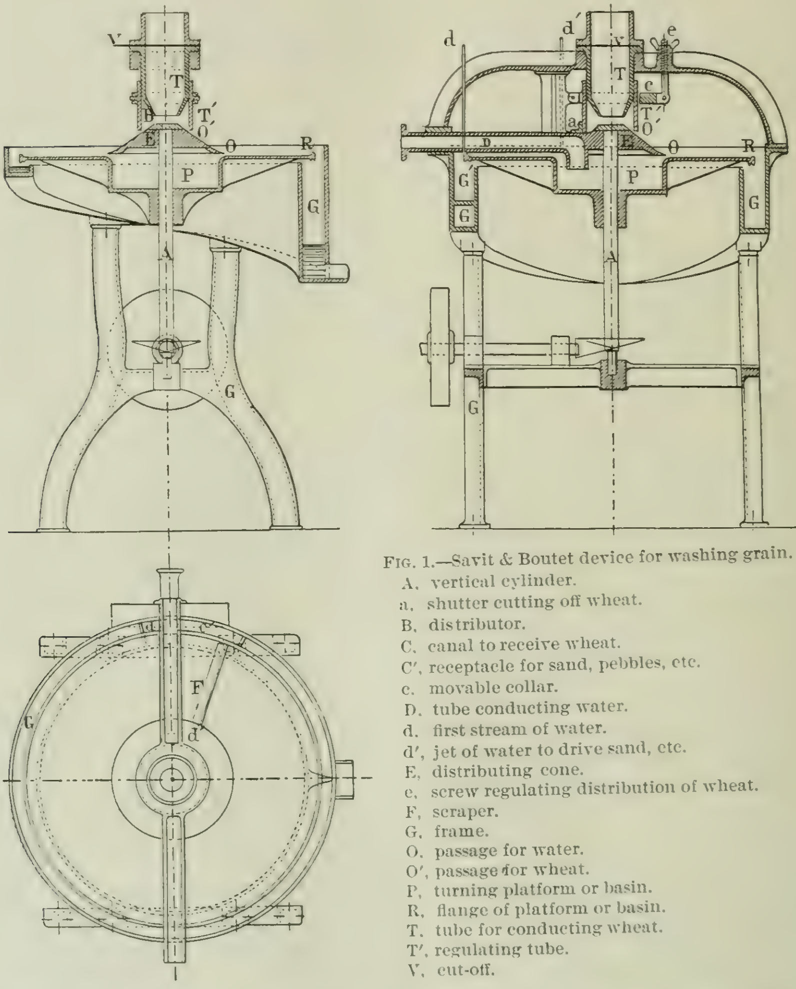


FIG. 1.—Savit & Boutet device for washing grain.

A, vertical cylinder.
a, shutter cutting off wheat.
B, distributor.
C, canal to receive wheat.
C′, receptacle for sand, pebbles, etc.
c, movable collar.
D, tube conducting water.
d, first stream of water.
d′, jet of water to drive sand, etc.
E, distributing cone.
e, screw regulating distribution of wheat.
F, scraper.
G, frame.
O, passage for water.
O′, passage for wheat.
P, turning platform or basin.
R, flange of platform or basin.
T, tube for conducting wheat.
T′, regulating tube.
V, cut-off.

The water arriving by the tube *D* fills the basin, and playing with more or less pressure from the circular orifice *O* spreads over the shallow basin and drains over the flange *R*. The depth of the water passing over the flange should be sufficient to allow the passage of a grain of wheat. The wheat distributed from the orifice *O* drops first upon the cone *E*, then to the water, whence it floats, and is swept over *R* and falls into the canal *C*, the inclination of which is such that the grain goes quickly to the drying column, where it is immediately dried. The distance across the surface of the basin is such that pebbles and other foreign particles have sufficient time to sink.

As the basin rotates continually, the foreign matter remaining is brought under the jet of water *d′* which is so regulated that any heavy grains of wheat remaining, and which might otherwise remain with the stones, are swept over the flange also between two jets of water; there remain then only bodies of greater density than wheat, which are forced below the flange *R* and thence fall into the canal *C″* and are cared for in a special receptacle. Thus it will be seen that the operation is performed without the immersion of the wheat, since the latter floats and is not much dampened. The operation of dampening

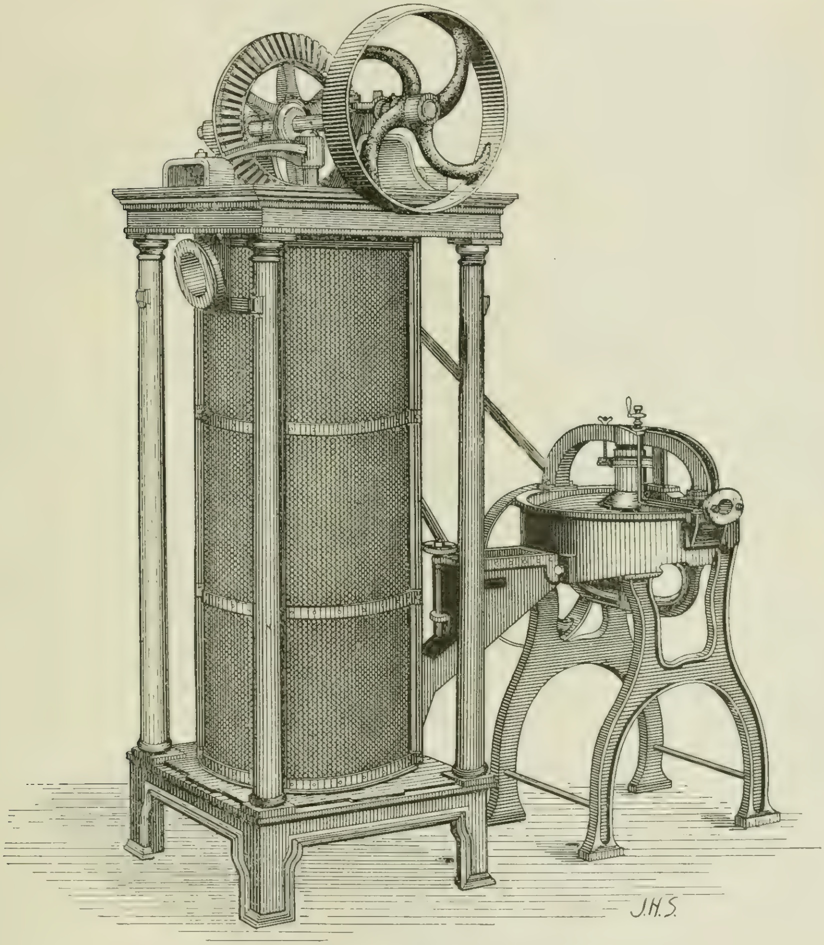


FIG. 2.—Drying column, with scouring device for washing grain.

begins after the wheat falls into the canal, and lasts until it enters the drying column. This operation continues about three seconds. The drying column designed originally by Pierre Cardilhac is shown in fig. 2, and consists of a perforated cylinder through which the grain passes rapidly, and is frequently so dry that it must be redampened before the milling begins. The entire device is capable of treating 30 hectoliters (67 bushels) per hour.

PERCENTAGE OF SEMOLINA IN DIFFERENT WHEATS.

The manufacturers of the best quality of semolina, known as "S. S. S.," expect the resultant product to be 60 to 65 per cent semolina, from 12 to 15 per cent flour, and from 18 to 20 per cent bran. This proportion is quite different when the native metadiné, or mixed wheats, are employed, in which event a smaller proportion of semolina is expected, varying from 30 to 40 per cent, inferior in quality and containing impurities which reduce its value. The proportionate amount of flour is greater with these wheats, and the quality of the flour is better than that resulting from the grinding of the strictly macaroni wheats. The grinding of the pure macaroni wheat into flour is very rarely attempted, although in Algeria a good deal of flour is thus made, and the bread is of good flavor and very nourishing. The manufacture of flour from macaroni wheat, in addition to other disadvantages, requires the expenditure of additional mechanical force.

IMPORTANCE OF CLEANLINESS.

The average hard wheat is said to contain from 8 to 12 per cent of moisture, which is considerably increased by the washing, as the process is now followed in Marseille. It naturally follows that the semolina and flour of hard wheat retain their virtues for a length of time dependent upon the season in which they are manufactured. In winter they will retain their original qualities for five or six months, while in summer one or two months is perhaps the life of the product in merchantable condition, after which worms are very likely to be found in it, in which case the semolina must be resifted and rebolted. The increase of these worms is prevented to a large extent in the French mills by attention to cleanliness. In those mills which are cleaned twice a year, where whitewash is used with liberality, very few are ever seen, while in others, where less attention is paid to details such as these, the timbers are covered with them.

THE MILLING PROCESS.

The American miller will probably add little in France to his knowledge of merely mechanical processes. Few, if any, machines of French invention are employed in the French mills, the Budapest process having been adopted and adapted to the peculiar local necessities. American winnowing machines are in general use. Neverthless, illustrations with proper explanation are submitted of several of the devices essential to the production of semolina.

In the milling of the semolina wheat, the arrangement of the machinery is not radically different from that required for the grinding of soft wheat into flour. (See figs. 3 and 4.) The scouring process is identical, but as the hard wheats used here contain a very much larger proportion of foreign matter than the soft wheats, the scouring is much more energetic, and is followed by a much more active winnowing process. The wheat, having been first dry-scoured in separators, winnowing machines,

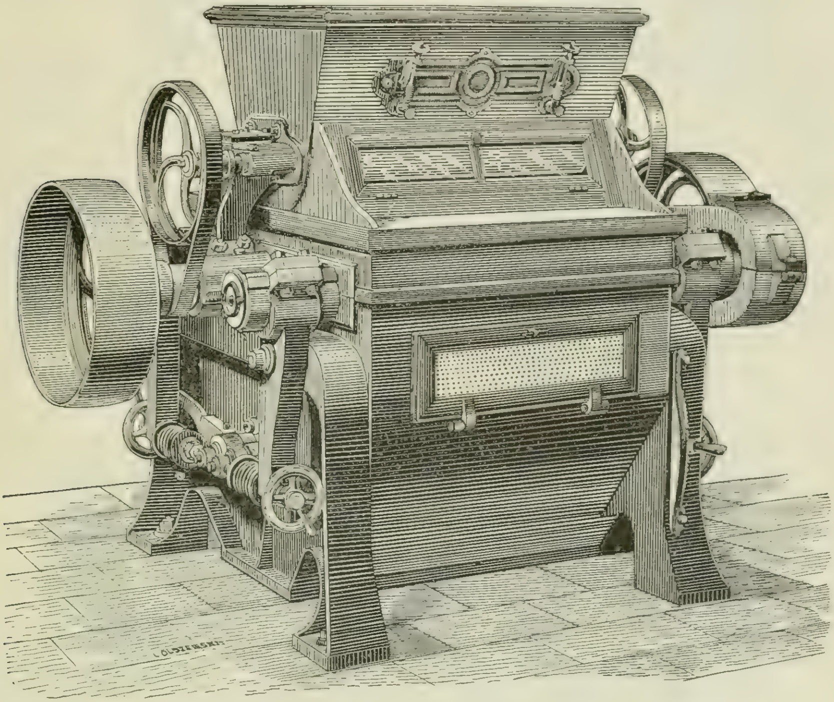


FIG. 3.—Typical French milling machine with four cylinders.

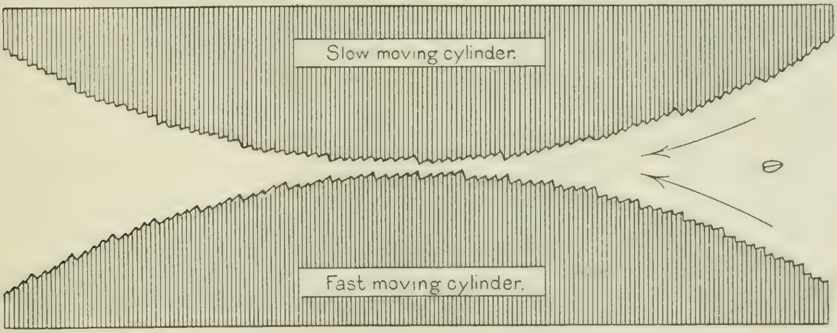


FIG. 4.—Cross section of rollers used in producing semolina.

and culling machines, goes to the washing machine, and after the washing is received in sacks or in bushel measures, where it reposes during the necessary time. After the period of repose (varying from ten to forty hours), it is beaten and blown and brushed, and is then ready for the first crushing.

The miller's object is to obtain the highest possible proportion of semolina, and the least possible proportion of flour. To do this, the cylinders work with no more pressure than is absolutely necessary in order that the moistened bran may detach itself from the wheat in large flakes and the grains of semolina be secured without being unnecessarily bruised. To facilitate this work there are ordinarily two crushing operations in addition to those to which soft wheat is subjected, during which the coarsest semolina, passing through No. 16 bolting cloth, is withdrawn. After the crushing all the products are classified on "planchettes" according to their size, and are then transmitted to the bolters, which clean them. The most important operation is the final winnowing for the refinement of the semolina, and in order that this may be done under satisfactory conditions, it is essential that the semolina shall first be classified according to size, well dried, and relieved of fine particles. Each class of the semolina thus obtained is then sifted separately, upon ventilated sifters, the dust and foreign matter being blown away, and the clean semolina dropping through the sieves, from which it is delivered into sacks ready for the market.

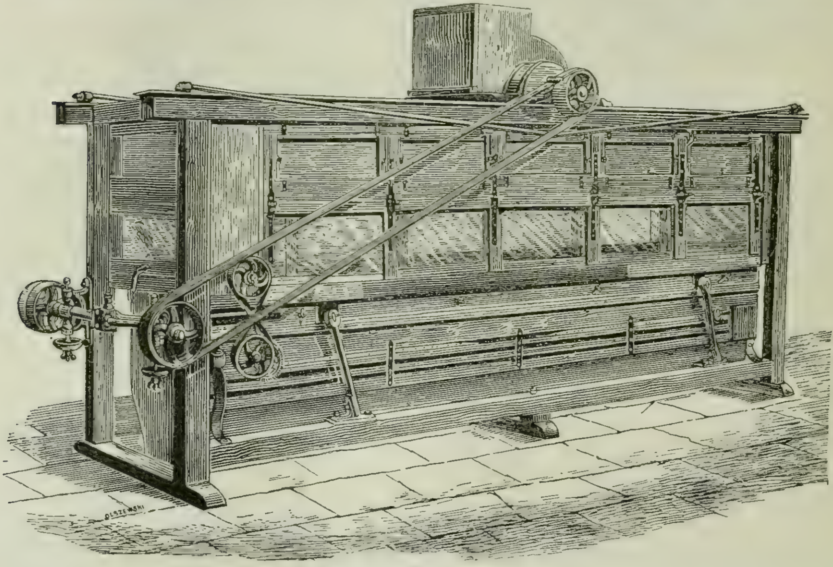
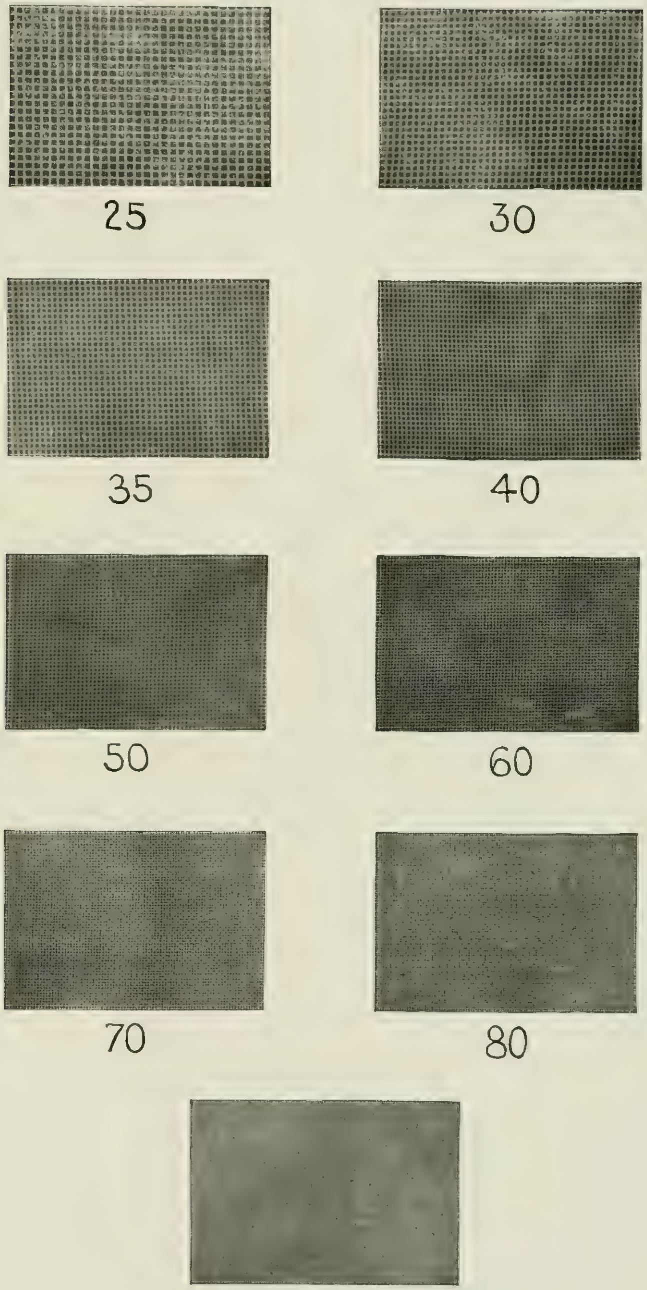


FIG. 5.—The sasseur.

CLASSIFICATION OF PRODUCTS.

The final operation in the production of semolina is performed in a machine known as a "sasseur" (fig. 5), the manner of operation (fig. 6) being as follows:



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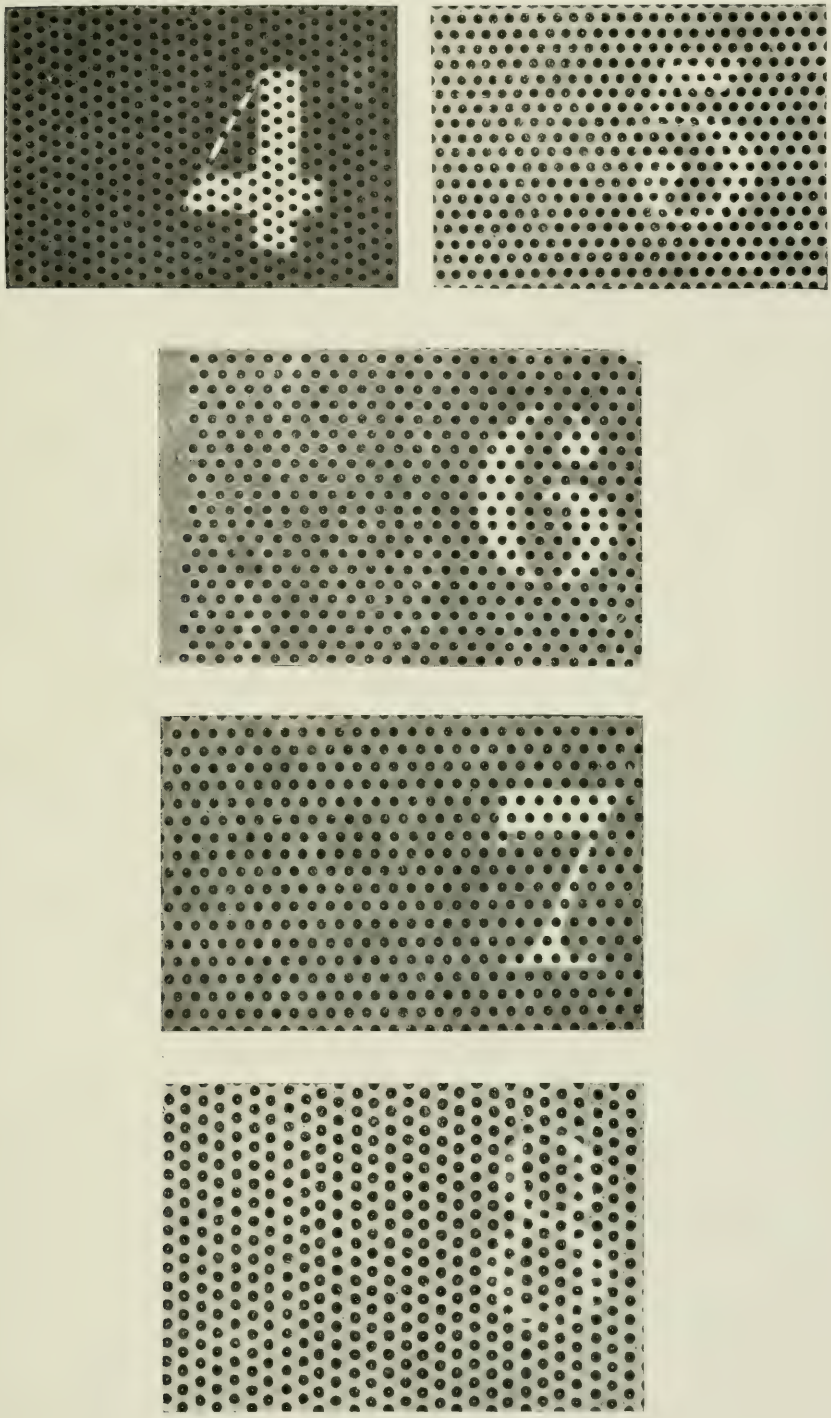
DIFFERENT GRADES OF BOLTING CLOTH FOR SEPARATING AND CLASSIFYING SEMOLINA.



SIEVES USED IN THE SASSEUR.

The unpurified and unclassified semolina is delivered upon the separator or sieve of waxed paper (fig. 6, A–A), upon which it is continually shaken while a current of air passes upward from below. The rounded, polished grains of semolina which are too large to pass through the sieve are carried forward in the direction shown by the arrows pointing toward the left, and is finally delivered into sacks. The smaller grains fall through the sieve, in the direction indicated by the arrows pointing downward, and are afterwards reclassified. The lighter portions (flour, etc.) are carried upward by the current of air, the heavier particles dropping backward onto the smaller sieves, B B, and the flour dust being expelled in the direction of the arrows pointing upward.

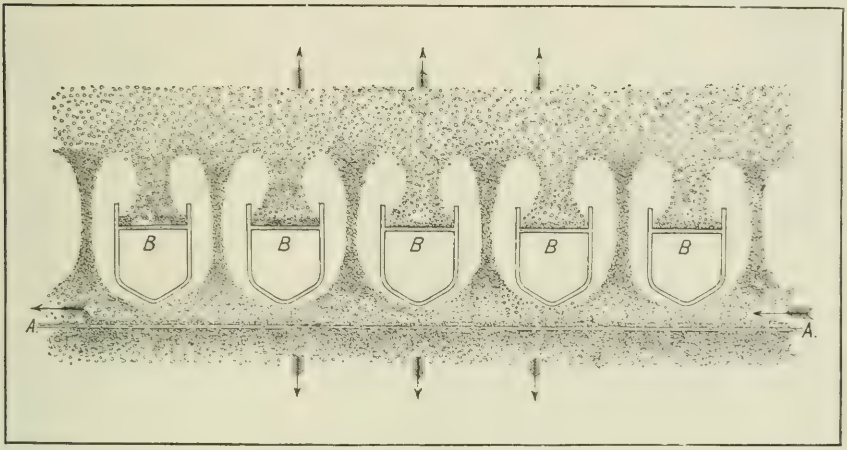


FIG. 6.—The sasseur in operation.

The French semolina is classified according to size, the trade terms being as follows:

Semolina sifted, passing through sieve—

No. 20 to No. 25	"G. G."
No. 25 to No. 30	"M. G."
No. 30 to No. 40	"S. S. S. G."
No. 40 to No. 50	"S. S. F."
No. 50 to No. 60	"S. S. S. F."
No. 60 to No. 70	"S. F. S."
No. 70 to No. 80	"S. B."

All the products passing through numbers 80 to 90 French silk, are classed as flour. (See Plates II and III.)

Of the flours that are produced during the manufacture of semolina from 10 to 12 per cent are known as "Gruau hard," and from 3 to 5 per cent as "Minot hard." The hard Gruaus are produced from the operations of crushing and classification, and are of fair quality. Minot hards are of inferior quality. All the other flours and products of the grinding, except those already enumerated, are classified as brans, and receive the following designations: (1) Flour, "F. B. D.;" (2) "Repasse hard;" (3) Coarse hard bran.

Under average conditions 50,000 kilos of hard African wheat will yield the following products:

Classification.	Quantity.	Percentage.
SEMOLINA.	*Kilos.*	*Per cent.*
S. S. S. G	3,200	6.40
S. S. S	15,180	30.36
S. S	4,800	9.60
S. S. S. F	6,670	13.34
	2,650	5.30
Total semolina	32,500	65.00
FLOUR.		
Gruau hard	7,000	14.00
Minot hard	1,500	3.00
Total semolina and flour	41,000	82.00
REFUSE.		
F. B. D. 3	9,000	2.00
Repasse	3,000	6.00
Coarse bran	4,500	9.00
Waste in cleaning[a]	1,500	3.00
Total product	51,000	[b]102.00

[a] Consisting of small grains of wheat, barley, weed seeds, etc.
[b] Excess of 2 per cent accounted for by admixture of water.

The average price of semolina is from 30 to 33 francs per 100 kilos ($5.79 to $6.36 per 220 pounds). As much as 40 francs ($7.72) and even 48 francs ($9.26) has been paid under exceptional market conditions, the lowest price recorded being 23 francs ($4.43) per 100 kilos. The wholesale price of macaroni, which contains practically no raw material other than semolina, averages from 48 to 50 francs ($9.26 to $9.65) per 220 pounds.

MANUFACTURE OF MACARONI.

While Marseille at the present time leads the world in the manufacture of semolina, this is not yet true of the edible pastes manufactured from semolina. There are in this city some 40 small manufacturers of macaroni, each averaging from 300 to 400 kilos per working day, and depending upon a local and restricted trade. There are 5 or 6 important concerns producing from 1,000 to 1,500 kilos each per day. The firm of Rivoire & Carret, for example, manufacture from 15,000 to 20,000 kilos per day, and have two factories in different parts of the city. Another house, that of F. Scaramelli Fils, which exports very heavily to the United States, turns out from 5,000 to 6,000 kilos per day. The firm of Rivoire & Carret have large factories also at Paris, Lyon, and Mulhouse in Switzerland. The total production of edible pastes in Marseille amounts to 45,000 kilos per day, and this is probably equaled by the production of Lyon. In Switzerland there are also very important concerns, and, as I said before, the business is steadily increasing everywhere.

THE PROCESS.

The generic term for edible pastes in France is "pâtes alimentaires." We are accustomed in the United States to speak of these articles as "macaroni," but in point of fact macaroni is merely one of a hundred different forms in which edible pastes are produced. The composition is much the same in all cases, the different designations referring to form and size. The method of manufacture is comparatively simple, as modern mechanical methods are simply enlargements of the old family process by which the housewife mixed flour and water, kneaded the batch, rolled it into sheets, cut it into strips, and hung it out to dry. In the modern factory the semolina is measured into a steel pan about 8 feet in diameter, within which travels a stone wheel. Water is added, the machine is put in motion, the wheel moves slowly around the pan, thus kneading the batch until it attains proper consistency. Just ahead of the wheel is set a small steel plow, to gather and turn over the mass so that it falls under the rim of the approaching wheel, thus guaranteeing an even kneading of the whole amount of semolina measured out. From the kneading machine the dough passes to steel presses (Plate IV, fig. 1), by which it is converted into marketable form. From the presses the product goes to the drying rooms, where it is seasoned, after which it is packed and placed on the market.

All of the foregoing is apparently easy and few pitfalls are observable. Nevertheless, before the batch is prepared for the petrin or kneading machine, a practical test is made with each lot of semolina to determine the amount of gluten it contains. A kilo of semolina is put into a basin of water and kneaded by hand until the starch and other matters disappear in the washing and the gluten remains in the hand. The loss of gluten by this method amounts to 60 grains in a kilo of semolina. The gluten remaining after the starch is kneaded out is weighed and the batch for the petrin is prepared with reference to the amount of gluten found in the raw material. Here is where skill and experience begin to count. If, for example, an attempt should be made to manufacture a given quantity of macaroni from a certain amount of high-grade semolina and the same quantity from the same amount of fine flour produced by grinding the same wheat, the macaroni produced from the semolina would be very unlike and very superior to that produced from the flour. The flour having been crushed into powder is so separated that what the macaroni manufacturer calls its "force" is completely lost, and the macaroni is brittle and dull of appearance. On the other hand, the macaroni made from the semolina would be translucent and elastic, and, after having been cooked, the lengths of the macaroni still retain their form. These are the qualities sought by the manufacturer of macaroni: A bright, clear appearance, elasticity before cooking, and sufficient "force" to retain the original form after having been cooked.

MIXING THE SEMOLINA.

There is more gluten in the Russian wheat than in the Algerian, and the semolina manufactured into macaroni without an admixture would not only be dark and dull, but would be very hard upon the machinery of the factory. Algerian semolina, on the other hand, if manufactured into macaroni, would be too brittle to satisfy the requirements of the trade. A mixture must therefore be made in which there will be from 45 to 50 per cent of moist gluten.

The important matter of mixing the different kinds of semolina together having been attended to, the water is next introduced into the steel pan, the quantity varying from 20 to 27 kilograms per 100 kilograms of semolina, depending somewhat upon the nature of the edible paste to be manufactured and the humidity of the semolina itself. This proportion is determined by the experienced judgment of the manufacturer. Very slight differences in the amount of water are necessary for the production of various kinds of pastes, the vermicelli requiring a shade less than any of the others. The mixture of semolina and water properly kneaded supplies the true macaroni, but with the increase in competition and changes in public taste, a demand has arisen for an edible paste in which eggs are kneaded, and manufacturers also introduce rice flour, corn flour, and potato flour. To satisfy an entirely local clientele, garlic is occasionally introduced. The same is true of edible pastes into which the juice of carrots, turnips, cauliflower, and cabbage is mixed. These varieties of the article are quite unknown in the United States. The rice, corn, and potato flours are only employed to affect the color of the finished product and the cost of the same. These adulterations are only used in the case of the cheaper macaronis.

The paste of the highest grade is translucent and of the shade of very light amber. Pure white macaroni may seem more attractive, but its color is often due to the admixture of rice flour. The cheaper hard wheats always produce a dark semolina, and their color must be toned up in order to make them marketable. In the case of macaroni of the first quality the whitening is brought about by the kneading process, which is continued from thirty-five minutes to fifty minutes. Ordinary paste is kneaded thirty-five minutes, and the extension to fifty minutes is only in exceptional cases and for the production of a superfine article. The difference between an ordinary white macaroni and that of an equally white cheaper macaroni can be distinguished by holding lengths of them up to the light. The rice-flour macaroni will be found to be dull white like a sheet of paper, while the thoroughly kneaded and better quality of macaroni will be translucent.

CURING OPERATIONS.

After the kneading of the paste and its manufacture into forms, the skill of the expert is again called into play while the curing process takes place.

In discussing the matter with me, Mr. François Scaramelli said:

> This is the most delicate feature of the business. I believe that it takes about twenty years to get a factory into thorough running order. For fifteen years I myself have given instructions to one of my most competent men on the subject of drying, in order to give to myself more personal leisure. Yet to-day if that man is left entirely alone, difficulty is likely to occur. To know exactly when the macaroni is "ripe," so to speak, and ready for the market, amounts to an intuition. It is absolutely impossible to establish cut-and-dried methods. Personal experience must be the only guide. It is right at this point, in my opinion, that the first efforts to manufacture macaroni in the United States have not succeeded. The promoters have not had sufficient patience in going about their work. They have expected to accomplish in a few years that for which we have required a lifetime of labor. I have seen some American macaroni, and my main criticism on it is that it is not solid, though in every other respect it leaves something to be desired. If a macaroni is permitted to "take cold," as I may express it, during the drying process, in spite of its condition as respects the quantity of gluten and the duration of the kneading process, it lacks the elasticity which a perfect macaroni should have. When the product is properly cured, one should be able to take a section a meter long, and, holding it up by the end, it should bend readily, like a whip, without breaking. The same macaroni improperly cured will break; it will break before cooking and it will be still more brittle after having been cooked. This elastic quality causes the macaroni after cooking to retain its original form, desired by all lovers of the food, while the inferior article melts together and becomes more like paste.

In all of the large factories the macaroni is dried in rooms in which the temperature is kept at about 70° F., except in summer, when the weather alone regulates this matter. Vermicelli and macaroni are hung on racks, and the edible pastes molded into forms are placed in drawers. This is the so-called "French system," and any variation in the temperature causes the macaroni to warp. The small manufacturers have great difficulty in curing their product, and it must be consumed within a week or so, or the deterioration in the quality is so rapid that customers protest. More carefully prepared macaroni, especially if it is packed in tight boxes, retains its excellence from six months to a year in ordinary climates, although every "gourmet" who cares much for this food insists that the sooner it is eaten after coming from the factory the better. I am satisfied that there is some truth in this claim, as I have frequently observed very marked difference in the quality of macaroni served upon my own table, when bought at the same shop and at the same price. This deterioration is what most strongly confirms my opinion that edible pastes will not become a staple article of diet in the United States until we have domestic manufactories so organized that the consumer may be always assured of fresh merchandise.

While the drying process in rooms seems to be best adapted to the manufacture of macaroni on a large scale, it is still claimed that the merchandise cured in the open air is better than that cured by artificial heat. Mr. Scaramelli attributes the success of a number of Neapolitan manufacturers who secure their semolina from Marseille to the fact of their adherence to this old-fashioned method. Many travelers can recall having seen in Naples, upon the roofs of dwellings, wooden frames with the family supply of macaroni drying thereon. Mr. Scaramelli himself has recently adopted this system (Plate IV, fig. 2) for a part of his output, and is well satisfied with his success. The process requires the closest supervision, as, after the merchandise becomes once dry, it is taken to a "chamber of repose," a ventilated but closed room, and after remaining there several hours is again hung in the open air for five or more hours, and then a second time is sent to the chamber of repose, after which it is taken to the packing room and placed on sale.

This frequent switching about of the macaroni from the open air to the chamber of repose and back again is caused by the fact that when first exposed to the open air the product begins to dry from the outside, and if permitted to remain too long would warp. To prevent this it is taken to the dark room before completely cured, where it straightens itself, the moisture from the center spreading throughout the thickness of the paste. When it is judged that the same degree of humidity exists in every portion of the macaroni it again goes into the open air, so that the remaining moisture may be expelled. Very much the same care is given to this drying process as to the seasoning of lumber, the object being to assure thoroughness and to prevent warping.

The open-air curing process is not applicable, of course, to the drying of the "petits pâtes" (the small forms—stars, circles, etc.) (Plate V), and Mr. Scaramelli has within a few months devised a system for treating them in large revolving cylinders of metallic netting in a room heated by steam. When his apparatus is fully completed these "petits pâtes" will be carried by pneumatic power in tubes from the pressing room to the drying chamber, where they will drop in a continual stream into the continually revolving cylinders. Each cylinder is capable of drying 120 kilograms every two hours. From the cylinder the "petits pâtes" descend by gravity to a mechanical sifter, after which they are placed in boxes.

Most of the mechanical operations in the factories are carried on by men; the majority of the labor is undertaken by women and girls. Men are paid from 3.50 to 4.50 francs (67 to 86 cents) per day; women from 1 to 2.25 francs (19 to 43 cents), and boys from 1 to 1.65 francs (19 to 31 cents) per day.

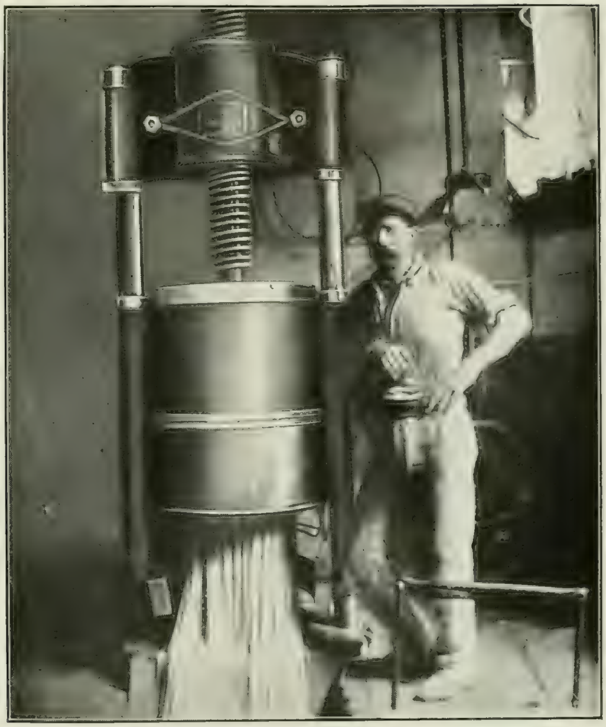


FIG. 1.—VERMICELLI PRESS AT THE FACTORY OF F. SCARAMELLI FILS.

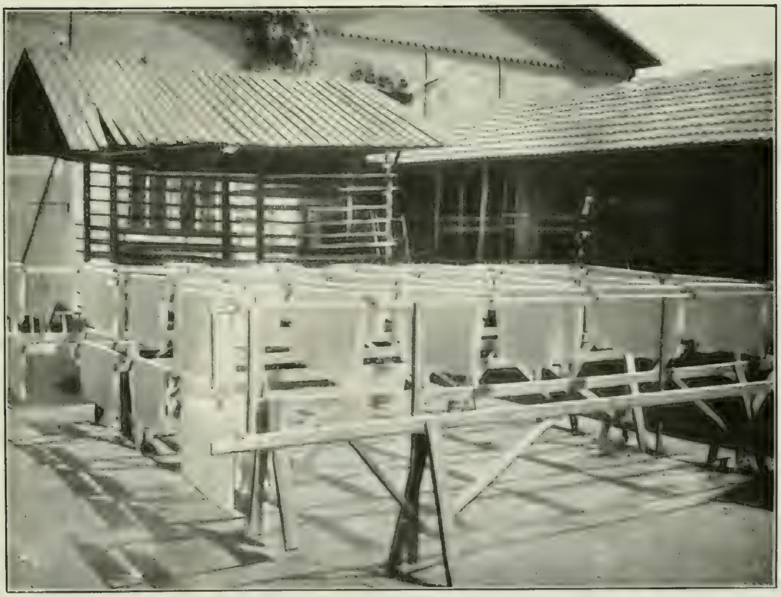
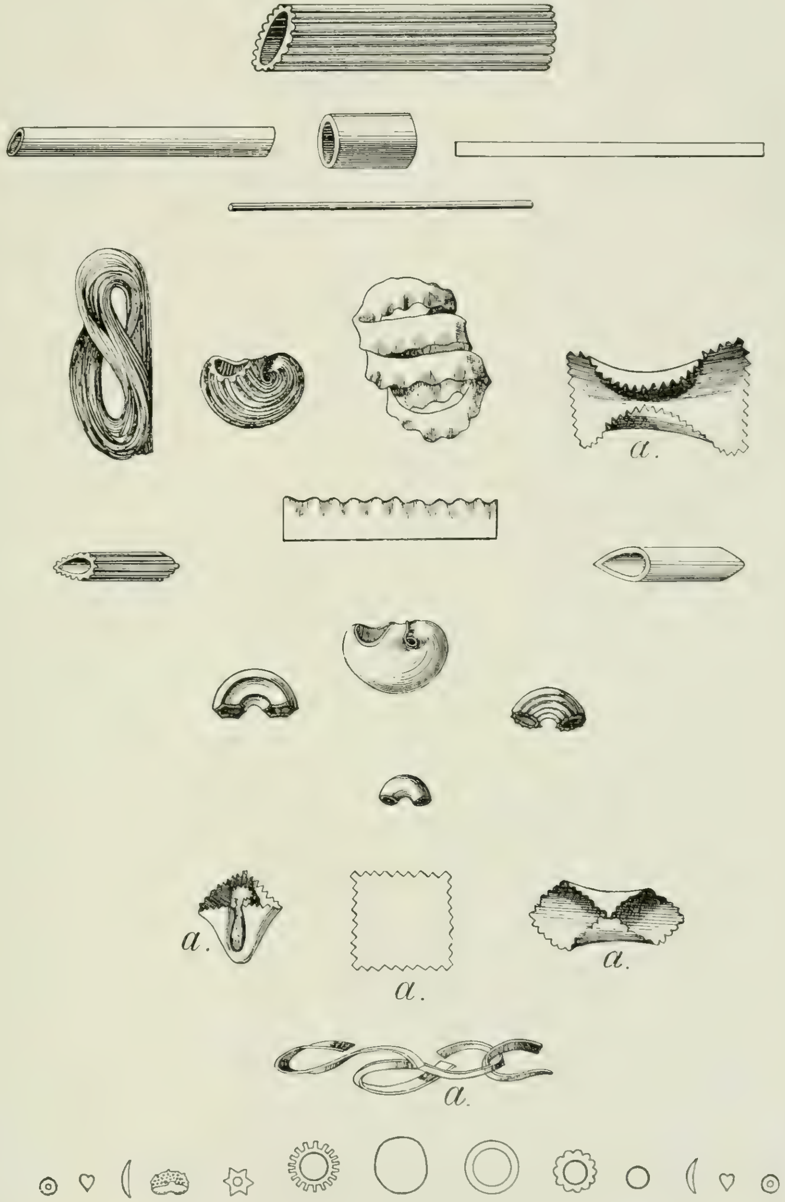


FIG. 2.—SECTION OF OPEN-AIR CURING DEPARTMENT AT THE FACTORY OF F. SCARAMELLI FILS.



VARIOUS FORMS OF MACARONI.

a. CONTAIN EGG.

The most careful economy is observed, all ends and broken pieces of paste being saved, and after the accumulation of a considerable quantity the whole is boiled for two or three minutes, then mixed with fresh macaroni, and worked up into macaroni of secondary quality.

DURUM WHEAT FOR BREAD FLOUR.

Before leaving Mr. Scaramelli's factory I was supplied by him with the following interesting information on the subject of flour: The best type of Provençal wheat, which is of the soft variety, and known as "Tuzelle," is very highly valued, and produces a very white flour. Another flour commonly manufactured in Marseille is known as the "Berdiansk." This is the product of the Russian wheat of the same name, and the flour is strong in gluten, and darker than the Tuzelle. The two are mixed in the city, generally in the proportion of 20 kilograms of Russian and 40 kilograms of Provençal. The mixture produces a standard type of bread in this city, and both of these flours are required throughout southern France, and are known as far north as Lyon. In Paris bread is manufactured wholly from local flour, and in order to secure the required amount of proteids bakers mix with their flour from 2 to 4 per cent of bean flour. However, even with this addition, the Parisian bread contains less gluten than that of Marseille.

TABLES OF EXPORTS, IMPORTS, AND PRICES.

Exports of semolina from Marseille, by countries.

Country.	1897.	1898.	1899.	1900.
	Kilos.	*Kilos.*	*Kilos.*	*Kilos.*
Russia	2,035,385	1,162,467	1,559,004	2,455,027
Sweden	756,601	675,089	934,590	1,115,884
Norway	492	....	985	7,929
Denmark	247,980	132,757	126,434	84,629
England	823,998	702,086	514,906	678,630
Germany	2,672,620	2,108,157	2,734,343	1,993,307
Holland	326,599	430,393	933,992	418,983
Belgium	200,300	261,489	272,676	279,453
Switzerland	10,493,385	8,709,651	9,308,214	10,671,287
Spain	773,841	168,845	143,002	347,417
Austria	637,220	467,220	482,836	367,675
Italy	1,715,822	899,773	2,146,192	1,595,505
Turkey	741,860	379,835	1,643,181	406,045
Greece	....	....	....	12,919
Malta	1,473,777	540,645	298,578	102,472
Egypt	2,580,577	1,250,657	940,803	1,135,301
Tripoli	1,070,100	321,943	184,160	774,536
Morocco	3,399,463	1,340,923	126,940	175,026
Algeria	5,012,324	5,352,750	2,465,432	2,125,969
Tunis	29,892,241	14,637,230	11,927,622	11,715,560
Neutral zone	....	....	491,941	509,444
Other countries and ships' provisions	748,488	930,307	23,988	28,486
Total	64,603,073	40,472,217	37,259,819	37,001,484

Exports of edible pastes from Marseille, by countries, 1899 and 1900.

Country.	1899.	1900.
	Kilos.	*Kilos.*
Russia	135	375
Sweden	11,520	19,503
Norway	6,982	31,679
Denmark	14,105	27,600
England	406,364	406,611
Germany	277,763	255,354
Holland	67,083	55,467
Belgium	577,886	533,145
Switzerland	64,615	43,940
Portugal	2,555	2,009
Spain	26,908	50,872
Austria	97,826	53,576
Italy	253,435	123,227
Roumania	17,267	8,706
Greece	....	7,359
Bulgaria	36,340	3,222
Turkey	192,644	183,559
Malta	103,586	120,936
Egypt	196,044	79,020
Tripoli	12,661	5,300
Morocco	13,491	7,497
Africa	....	7,850
Mauritius	39,980	55,594
India	18,105	32,055
Dutch Indies	13,194	....
China	7,241	8,035
Japan	4,162	[a] 5,330
Australia	9,687	9,554
United States of America	761,956	712,107
Mexico	97,400	83,291
Guatemala	13,473	....
New Granada	75,640	75,437
Brazil	16,213	6,218
Argentine Republic	16,848	15,084
Uruguay	....	233
Canada	40,726	14,876
British America, other	9,220	....
Haiti	12,963	10,215
Persia	....	51,049
Central America	....	5,889
Chile	....	661
Algeria	432,410	327,088
Tunis	148,989	95,464
Senegal	28,816	29,854
Guinea	4,895	10,628
Nossi Be	....	7,535
Madagascar	63,056	132,965
Réunion	3,062	22,521
French India	11,726	47,147
Indo-China	92,988	100,248
New Caledonia	56,231	62,649
French Guiana	28,308	46,980
Martinique	84,539	50,896
Guadeloupe	57,475	35,452
Other countries	80,048	....
Neutral zone	308,351	562,540
Provision to ships	220,746	269,851
Total	5,137,658	4,914,253

[a] Including Siam.

Importations of wheat at Marseille, by countries.

		Quintals.
1900.	Russia	3,815,988
	Turkey in Europe, and Danube principalities	199,513
	Turkey in Asia	51,288
	Australia	27,875
	United States	105,435
	Argentina	275,125
	Algeria	768,682
	Tunis	413,355

	Quintals.
1900. Naples	89
French ports	8,839
Total	5,676,189
1899	7,255,985
1898	9,886,243
1897	6,808,727
1896	7,735,008

Range of prices of semolina per 100 kilos at Marseille during the years 1885 to 1900.[a]

Year.	Highest.	Lowest.
	Francs.	*Francs.*
1885	32.00	27.00
1886	31.50	28.00
1887	31.50	26.00
1888	26.50	24.50
1889	25.50	24.00
1890	27.00	23.50
1891	31.00	24.00
1892	30.50	23.50
1893	27.00	22.00
1894	22.00	14.00
1895	16.50	16.00
1896	23.00	14.50
1897	28.50	18.00
1898	43.00	26.50
1899	27.00	22.00
1900	27.50	23.50

[a] Supplied by G. P. Bottazzo.

Values of declared exports of macaroni and vermicelli to the United States for the year 1900.

Country.	For quarter ended—				For the year.
	March 31.	June 30.	September 30.	December 31.	
France:					
Bordeaux	$4,346.55	$834.92	$25,012.66	$10,324.29	$40,518.42
Dijon	1,314.81		2,376.31	2,228.54	5,919.66
Lyon	17,096.00		10,326.45	21,203.75	48,626.20
Marseille	6,921.36	7,965.11	9,679.91	18,903.57	43,469.95
Other cities	270.90	297.76		593.48	1,162.14
Total	29,949.62	9,097.79	47,395.33	53,253.63	139,696.37
Italy:					
Castellamare di Stabia	118,046.69	130,183.39	103,041.63	149,742.25	501,013.96
Genoa	6,491.45	10,618.27	6,856.48	13,543.77	37,509.97
Leghorn	877.60		892.40	2,822.16	4,592.16
Naples	2,518.36	1,344.77	576.99	1,788.36	6,228.48
Palermo	19,643.00	6,735.00	4,518.00	24,004.00	54,900.00
Other cities	452.30	184.54	125.16	1,041.10	1,803.10
Total	148,029.40	149,065.97	116,010.66	192,941.64	606,047.67
Spain:					
Corunna (to Porto Rico)		1,163.60			1,163.60
Austria:					
Trieste				602.65	602.65
Grand total					747,510.29

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